PHYSICAL METALLURGY RESEARCH LABORATORIES

ANNUAL REPORT FY 1982-83

MINERALS AND ENERGY RESEARCH PROGRAMS

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W.H. Erickson, Director

Physical Metallurgy Research Laboratories

J.T. Jubb, Manager
Metal Processing Laboratory

D.W.G. White, Manager
Metal Development Laboratory

W.N. Roberts
Program and Planning Coordinator

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MICROMEDIA

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MICROMEDIA

FOREWORD

In 1982-83 the operating budget of the Physical Metallurgy Research Laboratories (PMRL) in the Mineral and Earth Sciences Program was $5.7 M with 131 person-years and in the National Energy Program (NEP) $0.76 M with 12 person-years. External research contracts supporting the programs totalled $1.90 M. Of this $0.42 M supported Minerals Technology projects while the major part of the funding, $1.48 M supported Energy Technology and NEP projects. Overall external research contract resources represented 23% of the total research resources. This is believed to be an appropriate balance between in-house and external activity and frees the program from the limitations imposed by gaps in available facilities and expertise.

The past year has seen the culmination of a short period of modest growth and renewal. Fresh talent, important updates of equipment and new project initiatives particularly under the NEP have given a new impetus to the research and a heightened consciousness of the role and responsibilities of PMRL in its collaboration with industry and university. On the other hand, the recession in the economic activity throughout the country has created a climate of restraint in the Federal Government which has had some impact on PMRL. It is anticipated that this policy will continue over the next few years.

One positive outcome of economic hard times has been strengthening of ties between the laboratories and the private sector. Whereas the severe financial constraints on R&D activity in industry, no doubt, has motivated an increased interest in contract research and collaboration with Federal laboratories, we see an underlying and welcome trend to greater cooperation between industry, university and government research in response to a growing recognition that the international competitiveness of Canadian manufactured products depends on effective use of national resources.

W.H. Erickson

AVANT-PROPOS

En 1982-83, le budget d'exploitation des Laboratoires de recherche en métallurgie physique (LRMP) était de 5.7 millions de dollars, avec 131 années-personnes, pour le Programme des Minéraux et des Sciences de la Terre et de 0.76 million de dollars, avec 12 années-personnes, pour le programme national d'énergie. Dans le cadre de ces programmes, les contrats de recherche accordés à l'extérieur ont totalisé 1.90 million de dollars. De cette somme, 0.42 million de dollars allaient à des projets relatifs à la technologie des minéraux alors que la majeure partie des subventions, 1.48 million de dollars, était attribuée à des projets relatifs à la technologie énergétique et à des projets PEN. Globalement, les ressources consacrées aux contrats de recherche externe ont représenté 23% des ressources totales consacrées à la recherche. On s'accorde à penser qu'il s'agit là d'une juste répartition des ressources entre les travaux internes et les travaux à contrat et que l'on peut ainsi dépasser les limites imposées par les lacunes dans les installations et les compétences dont disposent les laboratoires.

L'année passée a vu culminer une courte période de croissance modeste et de renouvellement. L'arrivée de nouveaux talents, une importante modernisation de l'équipement et de nouvelles initiatives en matière de projets, en particulier dans le cadre du PEN, ont donné une nouvelle impulsion à la recherche et ont montré l'importance du rôle et des responsabilités des LRMP dans la collaboration avec l'industrie et les universités. Par contre, la récession économique à l'échelle du pays a créé un climat de restriction au sein du gouvernement fédéral dont les conséquences se sont fait sentir aux LRMP. On prévoit que cette politique se poursuivra au cours des prochaines années.

Un aspect positif des difficultés économiques a été le renforcement des liens entre les laboratoires et le secteur privé. S'il est certain que les restrictions financières dans le domaine de la R & D industrielle ont rendu les travaux à contrat et la collaboration avec les laboratoires fédéraux plus intéressants, nous décelons et accueillons avec satisfaction un mouvement vers une plus grande coopération entre l'industrie, les universités et le gouvernement qui traduit une reconnaissance de plus en plus grande du fait que la compétitivité internationale des produits manufacturés canadiens dépend de l'utilisation efficace des ressources naturelles.

W.H. Erickson

HIGHLIGHTS

MINERALS RESEARCH PROGRAM

An experimental model of an X-ray stress diffractometer has been built for nondestructive measurement of residual stresses in engineering structures; after completion of software and hardware for full microprocessor control, field trials will begin in FY 1983/84. The instrument has particularly important design advantages over other X-ray models, having dual detectors and an oscillating high ouput X-ray tube, that permit stresses to be determined from a single X-ray exposure. These features avoid disturbing the geometry of the diffractometer relative to the specimen during measurement, and permit residual stress measurements to be made on large grained or textured material.

An extensive review of the microstructures found in linepipe steels, including weld heat-affected zones, has been completed; it explains various microstructures in terms of the thermomechanical history and phase transformations.

Under contract with McMaster University, calcium-deoxidized, non-leaded, free-machining steels have been developed, that have about twice the machinability of more conventional aluminum-deoxidized steels; significantly, two Canadian steel companies have displayed interest to the extent of providing experimental heats gratis.

Substantial progress was made in 1982-83 to modernize electron optical facilities, with the commissioning of a Cambridge 250 mk II scanning electron microscope and a Philips EM 400T scanning transmission microscope, - events which followed installation of a CAMECA microprobe the previous year.

In cooperative research with a large Canadian foundry, intercritical heat treatment of plain carbon and low alloy steel has been found to significantly improve low temperature mechanical properties, particularly in thick sections.

PMRL has continued to develop software for the Canadian foundry industry, with new programs for calculation of riser dimensions for castings and statistical control of foundry processes. A new casting method has been developed that incorporates advantages of both low pressure permanent mould and conventional disposable mould casting processes; a simple prototype system has been constructed and test castings poured successfully in cast iron, aluminum and a copper-base alloy.

From an extensive survey of Canadian cupola operations, PMRL has recommended simple changes in cupola design and operation to individual foundries, that could result in total savings of about two million dollars per annum when implemented.

PMRL continued to improve its experimental rolling mill facilities to simulate existing deformation schedules and explore new ones more closely. Computer programs have been written for automatic operational control of the mill by computer. The engineering design and acquisition of components for a high-speed screwdown system have been completed, with installation scheduled for FY 1983/84. Ingot reheating capability has been upgraded by acquisition of a large capacity globar element furnace with programmable control to permit simulation of commercial multi-stage reheating practice. The cam plastometer has been recommissioned and flow stress-strain rate data obtained for C-Mn and Ti-N steels of current and potential commercial interest.

In experiments, it was shown that a simplified analysis to predict mill loads, using cam plastometer flow-stress data, could be used with little more error than a more complex analysis.

A close correlation is now obtained between flow stresses computed from mill data for sheet-reduction schedules and those measured on the cam

plastometer. High values of flow stresses taken from mill data for plate-reduction schedules are now thought to be attributable to steep centre to surface temperature gradients, measured during rolling by embedded thermocouples. Future comparisons will include corrections for temperature gradient effects in thick sections.

In cam plastometer experiments, it has been shown that frictional effects can be ignored in flow stress calculations, for the specimen geometries employed.

Experiments applying a simulated paint bake cycle to galvanized continuously annealed dual-phase steels, bearing molybdenum and vanadium, indicate the resulting metallurgical changes do not adversely affect paint baking.

The effect of nitrogen on the notch toughness of the heat-affected-zone in welds is being studied for a number of nitrogen-bearing microalloyed steels in a cooperative program with Canadian industry. Experimental steels with less than 0.005% sulphur and 0.015% to 0.07% nitrogen have been made by the electroslag casting process. These steels have been controlled rolled to plate, and heat treated in the Gleeble 1500 to simulate heat-affected-zone structures. Examination of microstructures and toughness testing will be conducted in FY 1983/84.

Efforts continue to develop steels that can be heat-treated to produce rails of exceptional hardness, strength and wear-resistance. Fluidized-bed heat-treatment has produced pearlitic structures of high hardness, Rc 38 to Rc 46, but unfortunately the required transformation times are too rapid to be exploitable by commercial facilities. However, hardnesses of Rc 38-46 can be obtained at rail mill cooling rates with additions of 0.14% V and 0.07% N; hardnesses of Rc 38-39 are possible by increasing the nitrogen content and the cooling rate in the rail mill.

After consideration of ASTM, Lloyd's and CSA specifications for structural steel and ship plate, it has been concluded that steel conforming to CSA specifications G 40.21 Grade 260 WT or 350 WT, in the normalized or controlled rolled conditions, could be used for Arctic ship plate less than 50 mm thick and steel to CSA Grade 350 AT could be used in the normalized condition for plate over 50 mm thick. Investigation into the low fracture toughness of thick section, sand-cast, bronze been started to determine the foundry characteristics and mechanical properties of the "Sonoston" alloys used for propellers with high vibration damping characteristics.

ENERGY RESEARCH PROGRAM

In considering candidate metallic materials for tar sands tailings pipelines, corrosion resistant alloys, rather than abrasion resistant steels, have been found experimentally to be the more wear resistant, because corrosion governs the total wear rate.

Good progress has been made in developing a Canadian capability to manufacture advanced pressure vessels to process unconventional fuels. In the laboratory, rare earth additions were found to improve the resistance of 2.25 Cr-1 Mo pressure vessel steel to temper embrittlement. Under contract, the electroslag casting technique was used to produce experimental pressure vessel nozzles in 2.25 Cr-1 Mo steel, with excellent strength and notch toughness properties.

An experimental submerged-arc, narrow-gap-welding system has been installed in PMRL to weld thick sections. Two CANMET contractors are building narrow-gap-welding systems capable of joining Cr/Mo steel plate for pressure vessels up to thicknesses of 150 mm.

Studies of high strength steels (HSLA) for oil and gas pipelines are turning from evaluations of commercial linepipe, to studies supporting the development of higher strength linepipe steels. In other work modified controlled rolling techniques are being applied to reproduce the properties of current HSLA steels in thicker plate.

An understanding of the fundamental mechanisms that determines the useful properties of HSLA steels is being sought, with a view to optimizing processing parameters. The effect of rolling practice on austenite recrystallization and final microstructure has been determined. Under contract with McGill University, the kinetics of recrystallization and precipitation with additions of titanium are being investigated. Within the laboratory, a study of the effects of chromium and niobium on a simple niobium-base composition is largely complete. Under contract to McMaster University, the distribution and chemical composition of precipitates at various points in the rolling schedule of typical HSLA steels containing niobium and/or titanium is being studied by scanning transmission electron microscopy.

The effects of accidental dents and gouges on the failure mode of linepipe is being investigated. Pipe specimens with gouges have been pressure tested; preliminary results indicate that the present acceptance standards are conservative.

In research, partially funded by industry on stress-corrosion cracking in pipes transmitting sour oil or gas, standard tests for assessing the susceptibility to H_2S-induced cracking on nine pipes covering grades 290 to 483 are largely complete.

In an extensive research program on materials for offshore structures, which has recently begun, experiments on the effect of sea-water temperature on the rate of crack growth in corrosion fatigue has been completed for a structural steel. At 0°C, the crack growth rate is about the same as in air, but increases progressively with temperature to a rate at 25°C, five times that at 0°C. In research contracted to Memorial University, the corrosion fatigue life of welded joints in monoped structures has been found to be shorter than for comparable welds in simple T-joints; grinding the weld-toe did not improve fatigue life.

PMRL is undertaking research on materials for fluidized bed coal combustion, to support the possible construction of a full-scale facility in Nova Scotia to generate electrical power, in accord with federal "off-oil" policies. In particular, the performance of candidate alloys for boiler tubes will be evaluated in a series of ten 1000 hour tests in a pilot-plant fluidizied-bed combustor whose construction at Point Tupper, N.S. is almost complete. In allied work, a thermogravimetric system has been installed at PMRL and is being used to follow the reaction kinetics of four candidate Fe-Cr alloys in the temperature range 700°C-900°C in gas mixtures that simulate conditions in fluidized-bed combustors. Linear oxidation was observed to be the principal corrosion mechanism in the absence of ash deposits, but when metal surfaces were covered with calcium oxide or sulphate, the corrosion rate increased as a function of the deposit thickness. In other (contracted) research to develop materials for high temperature energy conversion processes, TiB_2 coatings have been sprayed on metal substrates. These specimens are being tested at PMRL for hot corrosion resistance and resistance to gases containing sulphur dioxide. In other work, a high temperature erosion test facility has been designed and is being constructed under contract for installation at PMRL.

SPECIAL HONOURS

The first prize in the Pretty Microstructures Exhibit was awarded to K. Gaugler, H.M. Hindam and D.P. Whittle for "Mystery Towers".

The second prize in the Scanning Microscopy class (SEM) was awarded to H.M. Hindam, D.P. Whittle and K. Gaugler for "Short Circuit Diffusion in Alumina Scales". H.M. Hindam, D.P. Whittle and K. Gaugler also received an Honorary Award in the same section for "Continuous Internal Alumina Precipitates".

M. Sahoo received the American Foundrymen's Society Best Paper Award in the Brass and Bronze Division for a paper on "Structure and Mechanical Properties of Slow-Cooled Nickel-Aluminum Bronze Alloy C95800".

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PART A. MINERALS RESEARCH PROGRAM

PROJECTS

360001 - CORROSION MECHANISMS
Project Leader - J.B. Gilmour

Work in this project was carried out on three separate elements: localized corrosion of stainless steel, abrasion corrosion, and slow strain rate tests of carbon steel in H_2S solutions.

The localized corrosion resistance of 904L stainless steel was determined using the concepts of the critical-pitting temperature and crevice-corrosion temperature developed by Brigham. The work showed that this high-molybdenum stainless steel behaved as expected in these tests and that the relative influence of various crevice materials was similar to that determined previously for other stainless alloys.

Abrasion corrosion research in another project has resulted in the development of a test procedure that allows the relative contribution of corrosion and abrasion in aqueous media to be determined. Work has been concentrated on adapting this procedure to experiments in a high temperature autoclave so that the effect of temperature on corrosion and abrasion can be studied.

The research on the use of the slow strain rate test to study the stress-corrosion cracking of carbon steel in H_2S solutions concentrated on developing procedures to allow the experiments to be carried out at temperatures up to 100°C. In addition, a series of experiments at room temperature confirmed that the reduction in area remained less than 15% at strain rates in the range 10^{-6}, 10^{-7}. As the fiscal year ended, the first tests at elevated temperatures had begun.

360002 - CORROSION OF MUNICIPAL WATER PIPING
Project Leader - G.J. Biefer

A survey of corrosion problems in Canadian soils, commissioned by CANMET, emphasized that underground corrosion failures of municipal water piping was reaching epidemic proportions. The problem is national in scope and of considerable consequence. However, the scanty literature available does not specify the failure mechanisms involved.

A contract was let to study the water pipe problem in the city of Calgary, as an example of municipal experience. An in-house interpretive history has been prepared for the period 1956-1980 that analyzes 13,561 pipe failures and classifies them according to pipe size, material, time of year and failure mechanism. A detailed analysis of 10 recent failures of grey (cast) and ductile iron pipes is nearing completion, having been delayed by difficulty in obtaining characteristic failures of grey iron during the unprecedentedly mild Calgary winter of 1982-1983, when very few water pipes failed.

The contractor will prepare a final report, presenting the main findings of the research in an easily digestible form that can be distributed to the waterworks maintenance departments of Canadian cities. He will also disseminate the findings and recommendations for failure counter-measures at regional conferences across Canada; this activity will extend into FY 1984-1985.

360041 - PLASTIC FLOW, FRACTURE AND STRESS ANALYSIS

Project Leader - W.R. Tyson

The objective of this project is to develop and maintain state-of-the-art expertise in technologies essential to fracture control.

During 1982/83, work has continued on elastic/plastic toughness testing and residual stress measurement. A novel approach to the estimation of crack length by the unloading compliance technique has been developed. The validity of a hole-drilling method for measuring residual stress using a high-speed drill has been established.

Plans for 1983/84 include the development of a chamber for controlled-temperature toughness tests, the testing of a technique for measuring surface stress gradients using the hole-drilling method, and the acquisition of instrumentation for dynamic toughness testing.

Technology transfer from this work occurs via many routes. The techniques that are developed are applied to a range of in-house and external projects such as round-robin tests on stress and toughness measurements. The expertise developed enables the scientists involved to contribute intelligently to standards and regulatory activities, and to respond authoritatively to requests for information on such topics as toughness specifications.

The practical experience gained is important for the guidance of fracture control strategies. It is being applied at present, for example, to the development of toughness standards for materials used in tanks for the transport of dangerous goods; the project is being carried out for the Department of Transport.

360042 - CANMET PORTABLE X-RAY STRESS DIFFRACTOMETER

Project Leader - D.W.G. White

Although the technique of measuring surface stresses by X-ray diffraction has been known and practised for more than 40 years, only recently by the development of small, position sensitive X-ray detectors, has the possibility of building a portable X-ray diffraction unit that will measure surface stresses in structures in the field been regarded as feasible. Measuring surface stresses by X-ray diffraction is the only truly nondestructive means of determining such stresses.

C.M. Mitchell of the Engineering and Metal Physics Section and D.W.G. White, Manager of the Metals Development Laboratory, examining an X-ray line profile from the prototype of a new X-ray stress diffractometer, which will be used to measure residual stresses in structures in the field.

X-ray diffractometers with different design characteristics, including portability in varying degrees, are becoming available commercially. An instrument that is inherently error compensating and can determine stresses in the surface of a specimen in situ, is also being developed in PMRL/CANMET. This unit will measure stresses on a spot of very narrow width in a single exposure of about 50 seconds - some instruments require two exposures before stresses can be calculated. Thus, among other things, the CANMET Portable X-Ray Stress Diffractometer can accurately measure stresses across a steep stress gradient and it does so in real time.

During the past year, an experimental model of the diffractometer head was made by a small company in Windsor. The head is currently being integrated with the other major sub-systems of the instru-

ment, particularly the instrument control and data processing sub-systems. The performance characteristics of the instrument will be used as a basis for the design of the first commercial prototype of the instrument to be made by the same company in Windsor. Two thirds of the cost of this development work will be funded by the Program for Industry-Laboratory Projects (PILP) in an agreement signed recently. The cost to PILP will not exceed $394K. The balance of the funding will be supplied by the company. An earlier market survey, also funded by PILP, indicated a potential North American market of 25 units during the first year of sales if the price per unit was of the order of $100K.

360051 - MICROSTRUCTURE AND PROPERTIES OF ENGINEERING ALLOYS

Project Leader - J.D. Boyd

This project explores the basic mechanisms of microstructure control, which are operative during processing of engineering alloys, and the relationships between microstructure and properties. Recent work has concentrated on controlled-rolled microalloyed steels.

It characterized all of the microstructural features which are observed, and summarized the current understanding of the origins of the various microstructures in terms of thermomechanical history and phase transformations.

A state-of-the-art quench-deformation dilatometer was commissioned and the transformation kinetics of a series of Nb,V microalloyed steels containing undeformed (recrystallized) austenite were determined. These experiments showed little effect of concentration of microalloy elements on the transformation behaviour.

The fracture toughness of simulated coarse-grained heat-affected zones with different prior austenite grain sizes and lath packet size was determined by Charpy and crack opening displacement tests. A technique was developed to simulate coarse-grained HAZ structures in tensile specimens, and hence to determine the tensile properties of HAZ's.

Scanning transmission electron microscopy was used to characterize the microstructure of bonded, partially acicular ferrite steels and to correlate it with cleavage fracture behaviour. By comparing STEM-, secondary electron- and back scattered electron images of the same areas, several ferritic and non-ferritic phases were clearly distinguished. Cleavage crack propagation was associated with carbide precipitation at interfaces.

360052 - DEVELOPMENT OF NON-LEADED, FREE MACHINING STEELS

Project Leader - D.E. Parsons

Phase I of this project (literature review) was completed in 1981 by McMaster University. It was agreed that Phase II would determine the effect on machinability of replacing Al deoxidation by Ca deoxidation. Subsequently, Burlington Steel supplied two 60 ton heats, an Al-deoxidized "control" heat, and a comparable experimental heat deoxidized by the addition of Ca and Nb. The machinability of the Ca-modified heat was approximately doubled - the machinability improving in the absence of Al_2O_3 inclusions. The modified steel contained both CaS and MnS with gehlentic oxide ($CaO.SiO_2.Al_2O_3$) inclusions but was free from Al_2O_3 (alundum) type inclusions.

Phase II of the program is now complete including two in-house (PMRL) elements, concerned with quantitative measurements of the inclusion content of the two Burlington Steel heats and microprobe analysis of the inclusions.

The Phase II work was successful in improving machinability by a factor of approximately two which was attributed to the absence of abrasive Al_2O_3 inclusions. By increasing the Si content to change gehlenitic inclusions to anorthitic inclusions, a further improvement in the machinability should be possible.

Two steel companies, have expressed interest and have offered to supply steel for the purpose of testing Ca-modification (elimination of Al_2O_3) in two commercial grades (1146 and 4140) used in the oil and automotive industries.

It is also hoped that the combination of Ca-deoxidation and the introduction of modern faster machining procedures will reduce the need for grade 41L40 steels with 0.3%Pb by replacement with a Ca-deoxidized steel containing little or no lead.

Phase III work, commencing, April 1, 1983, envisages a further improvement in the Burlington 1146 steel and Ca-modification of the Atlas 4140 steel by quantitative characterization of their inclusions and correlation with the McMaster machinability and property data.

360055 - ZINC-BASE FOUNDRY ALLOYS

Project Leader - M. Sahoo

In recent years three zinc-aluminum foundry alloys have been introduced which compete effectively with cast iron, aluminum and copper-base alloys for certain applications. However, optimum procedures for casting have not been defined and the ductility of the alloys is poor. After discussions with Noranda Research Centre, Cominco and others, a project was initiated to study the foundry characteristics and microstructural modification of the zinc-aluminum alloys.

An industrial consulting committee drawn from zinc producers and foundries has been formed to monitor the progress of the work.

CASTABILITY OF ZINC-ALUMINUM ALLOYS

Melting and casting practices for the 8, 11 and 27% Al alloys have been established using fluidity test patterns, simple plate castings and big blocks. Attention has been focused on the industrially important Zn-27Al alloy to eliminate shrinkage defects on the drag surface. Variation in gating ratio and addition of titanium to the melt appear to improve the casting quality.

MICROSTRUCTURAL CHARACTERIZATION

Microstructures of as-cast and heat-treated Zn-Al alloys have been characterized using optical and scanning electron microscopy. Titanium has been added to modify the microstructures of the 8, 11 and 27% Al alloys. Mechanical properties of the unmodified and Ti-modified alloys are being determined to study the effect of microstructure and chemistry on ductility. Similar studies will be done by adding Ni, B, Sr, Mn, etc.

360081 - DEVELOPMENT OF INSTRUMENTATION AND TECHNIQUES

Project Leader - R.H. Packwood

Several pieces of equipment have been installed this year: a Leybold-Heraeus automatic analyzer for hydrogen (H2A 2002) was commissioned for the analysis of hydrogen in metals on a routine basis.

Work on the anodic dissolution of steel and the reaction of the liberated hydrogen with a nitroxyl free radical is in progress. Studies involving thin layer chromatography, polarography and electron spin resonance spectroscopy of the free radical were used in establishing reaction patterns of hydrogen with the free radical.

The new Philips EM 400T transmission/scanning transmission electron microscope has been commissioned and calibration is complete. As well as being capable of conventional transmission microscopy with an ultimate resolution of 0.2 nm, the new instrument makes possible chemical and crystallographic characterization on a scale of the order of 10 nm.

The new Cambridge 250 mkII scanning electron microscope is working to specifications with resolution of the order of 5nm. The turbo-molecular pump can readily achieve chamber pressures of 3.75×10^{-10} Pa. The quality of the photomicrographs obtained is excellent and many projects are able to take advantage of this new facility.

360091 - COST RECOVERY IN MINERAL TECHNOLOGY DEVELOPMENT

Project Leader - W.H. Erickson

Over twenty independent metallurgical investigations were carried out in FY 1982/83 for a variety

of government agencies and for the private sector, employing PMRL's extensive mechanical testing facilities and electron-optical instrumentation.

360092 - TRANSFER OF MATERIALS DEVELOPMENT TECHNOLOGY TO INDUSTRY

Project Leader - R.F. Knight

The purpose of this project is to provide visibility to mature or developed technology in the Materials Development Technology sub-activity whose adoption, for whatever reason, has been delayed.

The only project element in this category at present, relates to attempts to develop improved abrasion-resistant plate steels by controlled rolling and direct quenching. Abrasion tests, that evaluated four experimental Mn-Mo-Nb steels and three based on the CNT360 composition, as well as three commercial steels, indicated that the relative abrasion resistance was governed by hardness only.

Direct quenching conferred no advantage in abrasion resistance, and the experimental steels exhibited inferior transverse impact properties.

370001 - EXPLORATORY FOUNDRY RESEARCH

Project Leader - R.K. Buhr

SUSPENSION CASTING TECHNIQUES FOR THE PRODUCTION OF CASTINGS

The introduction of inert, wettable fine solid particles into a melt has certain potential advantages. The suspensoid does not undergo liquid to solid shrinkage and thus the overall shrinkage characteristics of the melt can be significantly modified. It is possible that additional mechanical working can be used after solidification to produce some types of fibre reinforced composites. It may also be possible to introduce particles which will increase the strength without affecting other properties detrimentally. For example, improved abrasion resistance of electrical contacts might be achieved without decreasing their conductivity.

Preliminary investigations into this technique have demonstrated the importance of wettability of the particles without dissolution. Various coating techniques have been tried, but have not been fully successful due to rapid dissolution of the coating. Work will continue to find the appropriate combination of correct density, wettability and non-solubility.

370002 - TECHNOLOGY FOR THE METAL CASTING INDUSTRY

Project Leader - R.K. Buhr

INTERCRITICAL HEAT TREATMENT

Investigations have continued into this heat treatment technique to improve the low temperature properties of plain carbon and low alloy cast steels. Following cooling from the austenitizing temperature, the castings are reheated to a temperature within the critical range (between the AC1 and AC3 temperatures) and either water quenched or air cooled. The castings are then given their normal tempering treatment.

This project has been performed in cooperation with the Canadian Steel Foundry Division of Hawker Siddeley, Montreal, Quebec. The effect of intercritical heat treatment in improving toughness in cast steels has been evaluated for ASTM LCC and LC2 grades and for an AISI 8625 steel. Intercritical procedures were found to be most effective for thick-section castings, the greatest improvement being registered by the low-alloy LCC grade. Manganese content seems to be critical, with good results only at levels above one per cent. The toughening mechanism involves a grain refinement produced by intercritical normalizing, and a layered ferrite/tempered martensite structure produced by intercritical quenching.

EVALUATION OF COMPUTER PROGRAMS FOR RISER CALCULATIONS

Following feedback from industry, and an evaluation of the performance and costs of existing software the contract was altered from evaluation

of existing programs to the development of a new program. Close collaboration betwen the contractors and CANMET personnel resulted in the creation of a new risering program which compares favourably with existing programs and which has the potential for further improvement. It is anticipated the software will be made available to Canadian foundries at a nominal price through Canadian Patents and Development Ltd. (CPDL).

USE OF MICROCOMPUTERS IN THE FOUNDRY INDUSTRY

Statistical process control software has been developed and demonstrated at a workshop at Mohawk College and at four large foundries in Ontario. The software is simple to use and yet is highly effective in the analysis of foundry production data for the quantification of statistical variations in specific process variables and the identification of the causes of such variations. The software facilitates the presentation of the results in the form of control charts or other graphical formats that are easy to interpret.

370003 - DEGRADABLE SAND AND CORE BINDERS
Project Leader - R.K. Buhr

PROPERTIES OF NEWLY DEVELOPED DEGRADABLE SAND AND CORE BINDERS

Studies in this area were confined to methods to accelerate the curing of the binders, without affecting the working life of the mixtures adversely. A technique was devised to apply a moderately hard vacuum to the mixture. Full curing could be obtained in a period of about 15 minutes. In other tests, it was shown that the establishment of a continuous flow of air through the sand mass could accelerate the curing process. This flow could be accomplished either by pressurized air or by the application of a vacuum to a mould with an open surface. In both these cases, only the areas where a substantial flow occurred cured rapidly. Curing did not take place in the dead spots. It would appear that the formation of CO_2 bubbles is a rate controlling step in the curing.

PILP CONTRACT: DEGRADABLE SAND AND CORE BINDERS

The excellent levels of strength and their rate of development found in the laboratory on standard test pieces was not attained in the industrial trial. Curing was not achieved in the larger sections of sand used industrially. It was believed that the evolution of CO_2 during the curing operation was a rate controlling step. Because the techniques mentioned above are not considered a practical solution to the problem, efforts have been directed towards the addition of another chemical which will absorb the CO_2 and thus both accelerate and through-cure the sand mould. A non-toxic chemical addition has not been found so far that achieves this goal.

370006 - ELECTROSLAG CASTING
Project Leader - R.K. Buhr

PRODUCTION AND EVALUATION OF CASTINGS PRODUCED USING A SINGLE ELECTRODE

Techniques have been developed for the production of water-cooled moulds for use in the electroslag casting (ESC) process. These moulds are cast in pure aluminum complete with integrally cast water-cooling channels. It was calculated that this technique could reduce the mould cost by two-thirds. A number of circular castings 10 in. diam. (250 mm diam.) have been produced, mostly to an AISI 4340 composition. In addition, castings simulating a valve-body casting and a roll-shape casting have been made. It was demonstrated that the properties of the ESC material were similar to those obtained in rolled material of the same composition, and that the technique could produce shapes having equivalent properties to those obtained by forging.

ASSEMBLY OF EQUIPMENT FOR THIN-WALL CASTING

The design for thin-wall production has been completed and all parts required have been either ordered or made. Erection of the equipment is almost complete and preliminary studies will be starting in the next fiscal year.

H.-P. Guindon of the Foundry Section, stripping a cast aluminum mould from an electroslag-cast steel shape.

370015 - GRAVITY PERMANENT MOULD CASTING
Project Leader - R.K. Buhr

INOCULATION OF IRON CASTINGS MADE IN PERMANENT MOULDS

A series of castings have been produced in both grey and ductile iron compositions in a specially designed cast iron mould installed in the PMRL gravity permanent-mould casting machine. Various commercial inoculants were tested by casting rods 0.5, 1.2 and 2.0 in. diam. (12.7, 30.5 and 50.8 mm diam.), to produce standard tensile samples. It was found that chill-free hypoeutectic grey iron could be produced in the half-inch rods (equivalent to a quarter-inch plate). For ductile iron a fully carbide-free structure could be obtained only at high carbon equivalents. Silicon contents up to 4.0% were needed for the half-inch rods.

TEMPERATURE PROFILES IN PERMANENT MOULDS

A contract has been awarded to the Department of Mechanical Engineering of the University of Ottawa to develop a mathematical model of the heat flow in permanent moulds. A computer program has been written for the modelling of temperature distribution in a permanent mould and the casting for a two-dimensional case. This program has been adapted for use with the EMR computer. A program for a three-dimensional system with cylindrical symmetry is in preparation. A test casting for the establishment of parameters such as mould/casting heat transfer coefficients has been designed.

PRODUCTION OF CAST-TO-SHAPE DIES

Activity on this project element has been in two areas. Techniques employing the Shaw Process have been used to produce the cast iron dies, both for the low pressure work as well as the gravity permanent-mould casting studies. A variation in the standard practice for Shaw moulds has been devised, in which a male pattern and vacuum moulding techniques have been employed. The second area of activity has been in the preparation of a rig for testing candidate die materials for thermal fatigue. The test piece is heated by induction with the aim of producing a temperature profile at its surface similar to that produced at the surface of a metal mould when poured with liquid iron.

370016 - LOW PRESSURE DISPOSABLE MOULD CASTING
Project Leader - R.K. Buhr

DEVELOPMENT OF A LOW PRESSURE DISPOSABLE MOULD CASTING TECHNIQUE

A new casting method was developed which incorporates the advantages of both low pressure permanent mould and conventional disposable mould casting processes. A simple prototype system was constructed and test castings were poured successful-

ly in cast iron, aluminum and a copper-base alloy. Design and construction of a full-scale disposable mould casting system has recently been completed.

TEST CASTING DESIGN AND EVALUATION - LOW MELTING POINT ALLOYS

Extensive testing was conducted using existing dies and proprietary coatings to identify all production variables in the low pressure casting system that affect casting quality. These tests were then repeated using an existing die modified to produce a more difficult casting with a thin wall segment. A new die design has been devised, and the patterns required have been produced. The dies have been cast and will be available for use in the next fiscal year.

370017 - IMPROVED CUPOLA MELTING PRACTICE
Project Leader - R.K. Buhr

COST/BENEFIT ANALYSIS

Preliminary investigations revealed that the necessary relevant melting cost data were available. As a result a melting cost survey was conducted involving the establishment of standard casting methods, collection of data and the creation of special microcomputer software to facilitate cost analysis. Melting costs have been determined for 21 foundries and compared to cupola design and operating practice. Optimum cost targets have been established for each foundry using standardized costs and total potential savings of approximately $2 million per annum have been identified.

CUPOLA SOFTWARE SERIES

Development work on the CANMET Cupola Software Package was continued both at CANMET and at three cooperating foundries. This work has confirmed the accuracy and value of the software and preparations are in progress to offer the software initially to the Canadian foundry industry through CPDL. The American Foundrymen's Society (AFS) has requested permission to act as a distributor in the United States and discussions between CPDL and the AFS are underway to establish a mutually satisfactory agreement providing appropriate remuneration to the Crown.

EFFECT OF INCREASED TUYERE VELOCITY ON CUPOLA PERFORMANCE

This contract research was undertaken to establish a closely controlled and documented cupola operation at a commercial foundry in which the influence of tuyere velocity on melting efficiency could be isolated from other cupola operating variables. The work has been completed and the results indicate that tuyere velocity exerts a significant influence on combustion characteristics in the cupola. The participating foundry is now collaborating with CANMET with follow-up work to modify their cupola operating practice to take advantage of the new combustion conditions resulting from the use of high-velocity tuyeres.

370032 - ROLLING MILL PROCESSING TECHNOLOGY
Project Leader - A.F. Crawley

Resources within this project have been applied in three directions: in-house research, development of facilities for future research and contract research.

To assess the validity of applying theoretical equations to predictions of load and power requirements in rolling, two avenues were explored. First, predicted mill loads based on the theoretical analyses of Sims and Hockett and using cam plastometer flow-stress data were compared with mill data. Correlation of mill data with Hockett's analysis was slightly superior but not sufficiently so to justify its use in preference to the much simpler Sims' analysis.

Second, an in-depth study was undertaken of the influence of inhomogeneities in through-thickness deformation on mill loads predicted using Sims' analyses and cam plastometer data. Flow stresses computed from mill data were twice those measured on the cam plastometer for plate-reduction sched-

ules but approached agreement for sheet reduction schedules. This variance in stress was evaluated in terms of roll-pass geometry and strain and temperature gradients though the thickness. Quantitative measurements using embedded markers and thermocouples demonstrated that strain was uniform in a through-thickness direction for ingot to plate-rolling but that a steep centre to surface temperature gradient prevailed in gauges greater than 35 mm. As a result of this study, future computation of yield stresses from mill data will incorporate corrections to account for the effects of geometry and through-thickness temperature gradients.

Staff of the Metal Forming Section, conducting tests on the PMRL/CANMET experimental rolling mill, to establish rolling schedules for a thick-gauge linepipe steel.

The cam plastometer is now fully operational and flow stress-strain rate correlations have been completed on C-Mn and Ti-N steels. The influence of friction on recorded die pressures and, consequently, of flow stresses was re-examined in the light of recently reported work. This study demonstrated that for the geometry of specimens used on the cam plastometer, corrections for friction could be ignored.

Plans to upgrade the cam plastometer to simulate the hot rolling of strip have been completed. The first step in the upgrading has been the acquisition of a micro-computer for experimental control, and data acquisition and processing.

Work has continued on the development of software for automatic control of mill operation for future research on rolling processes. Computer programs have been designed leading toward control of roll speed and direction and speed and direction of the roll-separation drive system. Roll separation was monitored by software control in tests designed to develop a slowing and stopping procedure at a prescribed mill gap. These tests were unsuccessful and programs were written that control the mill gap within a prescribed rolling schedule, with a standard deviation of 0.125 mm.

The engineering design and acquisition of components for a new high-speed screwdown system have been completed. This system which will be installed in 1983 will allow significantly more control of interpass time and enable more precise simulation of industrial processes for modern high-strength steels. Preliminary work to interface the new unit with the PDP 11/23 microcomputer is in an advanced state.

Finally, the ingot reheating capability of the rolling mill facility has been significantly upgraded by the acquisition of a large capacity globar element furnace with programmable control for pilot-scale simulation of multi-stage reheating practice.

In contract research, investigation has continued into the causes and development of processes to minimize the undesirable duplex grain structure which develops during controlled-rolling of microalloyed high-strength steels. "Critical grain size" criteria were developed to describe dynamic recrystallization in hot compression of annealed and prestrained austenite. These criteria have provided new insight into the mechanism of static recrystallization in hot-rolled austenite. Subsequently, static recrystallization start and finish times were established for simulated roughing and finishing stages of controlled-rolling deformation. These measurements determined the deformation and temperature conditions under which complete recrystallization occurs during roughing and under which recrystallization can be avoided.

370034 - FORMABILITY AND PROCESSING OF SHEET STEELS

Project Leader - A.F. Crawley

The requirements of the automotive industry for a wide range of sheet steel grades (plain carbon, microalloyed, solution strengthened, and dual-phase) under increasingly stringent specification tolerances has imposed stricter processing requirements on the sheet producers. These quality requirements have, in time, spurred the need for a greater understanding of the interaction of formability and microstructure in order to obtain the optimum benefits from different grades. A major shift is also underway to replace hot-rolled grades by cold-rolled grades.

Research on the in-line galvanizing of continuously annealed Mo and V bearing dual-phase steels was extended to the influence of a simulated paint-bake cycle on the strength of the base steel. The results indicated that metallurgical changes accompanying in-line galvanizing do not affect the response to paint-baking.

The computer program for data gathering and calculation of tensile parameters relevant to formability was modified and enlarged to select and output definitive data. This same program has been enlarged to calculate strain hardening parameters plotted using a cubic spline. These plots are then used to compare the influence of microstructural variations on ductile flow. A program was developed using a strain-rate change, which is a routine step in the tensile testing procedure to calculate strain rate sensitivity. The program is being further refined to resolve some output data inconsistencies arising from discontinuous metal flow and sensing of the load change after the increase in strain rate.

In contract research, fractographic studies have been undertaken to gain insight into the ductility-strength relationship in dual-phase steels produced by different processing routes. Results indicate that the inferior ductility of batch-annealed compared with continuously-annealed steels has its origin in the ferritic rather than the transformed phase.

370035 - FLUIDIZED BED METAL PROCESSING

Project Leader - A.F. Crawley

The demand for improved properties in shaped steel products together with processing economics has created an interest in fluidized-bed technology for in-line heat treatment to obtain controlled cooling and transformation. Earlier work has shown that uniform properties throughout a complex cross-sectional shape are attainable using proper consideration of product shape and the direction of air-flow. Rail, for example, is an important candidate product for fluidized-bed processing.

The techniques developed earlier in the project have been adapted extensively to other projects on rail-steel development and accelerated, controlled cooling of linepipe grade steels. The pilot-scale bed has been upgraded by the installation of new higher current elements to permit more rapid "heat up" and greater flexibility of operation.

370036 - Near Net Shape Forging

Project Leader - A.F. Crawley

Near-net-shape (NNS) forging is a specialized approach applied to forging and roll-forming tech-

nologies to produce complex shapes to almost final dimensional specifications. Major economies are achieved by reduction or elimination of machining to size and material savings are made by optimum use of the initial feedstock. NNS has been applied mainly to highly specialized and expensive materials. Significant benefits, however, are also attainable by application of the technique to more common materials such as steels and especially to achieve finished products in which the deformation technique has achieved significant thermomechanical treatment.

The initial phase of the work has been completed with a review report on the modelling of metal deformation processes based on state-of-the-art finite element methods and related fields. Areas for research in the next phase of the project have been identified and recommendations made for the development of models of plastic flow behaviour.

In contract research, an investigation is underway into an assessment of the cold forgeability of various grades of steels. Strain paths and the influence of inclusions that lead to failure are being examined. The ultimate objective is to upgrade the strength levels of steels that can be satisfactorily cold forged but which are warm forged at present.

370052 - WELD MECHANICS
Project Leader - J.T. McGrath

The objective of this project is to develop the experimental and numerical methodology to determine and predict residual stresses and distortion resulting from the welding of steel structures.

In the current experimental program, the residual stresses that develop in welds are calculated using the finite element method. The finite element work is being performed under contract at the University of Waterloo. The data required for the finite element calculations have been obtained by monitoring the thermal/mechanical behaviour during the preparation of single-pass submerged-arc welds in stainless steel.

The residual stresses developed in the single-pass welds will be measured experimentally at PMRL using X-ray diffraction and hole-drilling techniques. The experimentally determined values will be compared with those calculated by the numerical method.

370053 - THERMAL/MECHANICAL SIMULATION OF METALLURGICAL PROCESSING
Project Leader - J.T. McGrath

The improvement of metallurgical processes such as continuous casting, hot working and welding may require costly production trials to develop new operating procedures. The Gleeble 1500 thermal/mechanical simulator, which can simulate the thermal/mechanical operations involved in many of these processes, is used to determine the effects of changes in process operating parameters. The information gained from these laboratory-based studies can be implemented in full-scale production procedures.

The overall aim of the project is to develop an understanding of metallurgical processes through the use of the Gleeble simulator, leading ultimately to improved commercial process efficiencies.

A cooperative program on continuous casting has been established with the Canadian steel industry. A program simulating continuous-casting operations has been developed in the Gleeble 1500. This program involves the melting and solidification of a steel sample. Hot ductility tests are performed in situ at various temperatures following solidification.

In the coming fiscal year, the response of a range of steel compositions to this continuous-casting program will be studied.

In the simulation of welding processes, the effect of energy input on the microstructure and notch toughness of the heat-affected zone of vanadium bearing microalloy steels has been determined. This work relates directly to the fabrication of large diameter pipelines and offshore structures.

370054 - THE EFFECT OF NITROGEN ON WELD NOTCH TOUGHNESS

Project Leader - J.T. McGrath

The advancement of BOF steelmaking has led to the development of low sulphur steels. The reduction of sulphur can cause an increase in nitrogen content (0.015%).

Pipe manufacturers and pipeline owners have identified the potential problem of reduced notch toughness in the heat-affected zone of pipe welds resulting from the presence of high nitrogen levels.

The objective of this project is to determine the effect of nitrogen on the notch toughness of welds prepared in steels for linepipe and offshore structures.

A cooperative program has been established with the Canadian steel industry to study the effect of nitrogen on heat-affected-zone notch toughness of a range of nitrogen bearing microalloy steels. A program for the simulation of the coarse-grain heat-affected-zone region has been developed for the Gleeble 1500 machine. The electroslag casting process has been used to make a series of steels with low sulphur (0.005%) and a nitrogen content ranging from 0.07% to 0.015%. The steels are controlled rolled to plate.

The future program will be to evaluate the microstructure and notch-toughness properties of the simulated heat-affected-zone specimens.

370071 - HEAT-TREATED RAIL

Project Leader - D.M. Fegredo

Rail users and manufacturers are increasingly aware that good-quality premium rails are a necessity on curved track carrying a high-density traffic of 100-ton unit freight trains. The current generation of premium rails (Rc 36) have to be transposed every 6 or 9 months because of their relatively high wear rate.

The principal objective of the CANMET heat-treated rail project continues to be therefore, the development of hard, strong, wear-resistant rail; two approaches were investigated in the past year. The first of these was a continuation of experiments with fluidized-bed cooling to control transformation temperature and the second was concerned with the effects of varying Al, N and V concentrations on the hardness and strength of Cr-V premium rail steels. The fluidized-bed work was largely successful in producing pearlitic structures of excellent hardness (Rc 38 - Rc 46), strength, and comparatively good toughness. However, transformation times are still unsuitable for production requirements. Experiments are planned on compositions that will make commercial production feasible and guarantee high hardness without sacrificing the pearlitic structure.

The second approach showed that hardnesses of Rc 35-36 are obtained at rail-mill cooling rates with additions of 0.14% V and 0.007% N. Higher hardnesses of Rc 38-39 are obtained by increasing the cooling rate and the percentage of nitrogen.

Wear work continues with the collaboration of the NRC Tribology Laboratory in Vancouver and under contract with the Technical University of Nova Scotia. Wear tests, simulating heavy duty service on curved track, have been carried out on many pairs of disks with varying microstructure and hardnesses. The data obtained are being assessed and will be correlated with optical and transmission electron microscopy observations and microhardness measurements of the worn specimens.

Recent results indicate that very fine grains are formed in the highly work-hardened structure within a few microns of the worn surface. In addition, optical work on worn, mixed (martensite-bainite) structures reveals cracks associated with the very hard (Rc 65) martensite particles. The mixed structures relate to partially transformed alloy rail welds.

Techniques have been established to obtain the fatigue crack propagation rates and threshold stres-

ses of rail steel compact tension specimens. Critical stress intensity (K_{1C}) values are obtained as a by-product of the tests. The knowledge of rail steel fatigue characteristics is considered necessary because many common rail defects are caused by fatigue and can lead to rail failures and derailments unless they are detected in time. The extent to which cracks grow before failure occurs depends on the particular K_{1C} value of the steel. The preliminary crack growth, experiments with a computer-controlled MTS machine on a commercial rail have given results that appear to be valid.

370072 - MARINE MATERIALS
Project Leader - R. Thomson

The main focus in this project continues to be the generation of data relevant to the specification and performance of steel ship plate for ice-breaking vessels.

A detailed collation of structural steel and ship plate data to CSA G40.21, ASTM 131 and Lloyd's "Rules" has been performed. It was concluded that the requirements for ship plate 20 mm to 50 mm in thickness could be met by CSA G40.21 Grades 260WT or 350WT in the normalized or controlled-rolled condition. For applications requiring greater than 50 mm thickness, e.g. low-strengthening or ice-belt reinforcement, the critical toughness requirements (40J CVN at -55°C) may be met by normalized plate to CSA G40.21 Grade 350AT or to Lloyds Grade LT-60. Current work on the fracture toughness and weldability characterization of both 350WT and LT-60 grades is referred to in project 420604.

The laboratory continued to provide technical support for the materials interests of the Canadian Coast Guard at a variety of levels. As an adjunct to in-house research on the toughness characterization of ship plate, samples of both A and D grade steels from an ice-breaking freighter were subjected to failure analysis. It was noted that while both samples had undergone considerable plastic deformation at low temperature (~ -25°C), the plastic strain in the A grade material culminated in a brittle propagating crack. Arrangements have been made to obtain a detailed inspection report on the vessel in question in order to obtain field data on fatigue-crack incidence and weld corrosion.

Laboratory work on weld corrosion has continued. Corrosion tests of three ship steels (Grades A, E, and EH36), welded with three electrodes (E 6011, E 7018, and a special alloyed rod conforming to E 8018) were started on apparatus constructed previously and patterned after a machine developed by the Swedish firm ESAB. These tests are designed to demonstrate that it is possible to produce corrosion in the laboratory similar to that observed on icebreakers operating in Canadian waters.

A sample of hull plate containing a weld from an icebreaker operating in the Beaufort Sea was examined during the year. This sample showed corrosion similar to that seen on other icebreakers with the weld metal corroded preferentially with respect to the hull plate. However, the hull plate was also heavily corroded with the corrosion primarily taking a pitting type of attack. There was no accelerated attack of the heat-affected zone.

Work on the general aspects of Arctic marine corrosion has been pursued using long-term sea water exposure. Four racks of corrosion specimens each containing samples of 21 different alloys were placed in Barrow Strait south of Resolute NWT by the Department of Fisheries and Oceans in April of 1981. Unfortunately only one rack was recovered in April '82. One rack was lost when a part of the mooring failed, and the other two racks were on a mooring that could not be located. (Unusual ice conditions are believed to have snagged the subsurface buoy and moved the moorings. The rack that was recovered was found some 75 km from where it was placed).

Analyses of the specimens recovered showed that corrosion rates in the Arctic were not significantly different from those in more southerly waters.

In the area of welding technology, new equipment for submerged-arc one-sided tandem welding has been commissioned and used to produce butt welds on 25 mm plate specimens. This research will determine if this high energy, high productivity process can be utilized without detriment to the fracture toughness of the HAZ or the weld metal.

370073 - NAVAL MATERIALS
Project Leader - M. Sahoo

The research work undertaken in this project is partially supported by a contribution from the Defence Research Establishment Atlantic (DREA) of the Department of National Defence (DND). However, the work is also of interest to the Canadian Coast Guard Service (CCGS), Canadian Stone Marine Ltd., and other Canadian brass and bronze foundries.

The work on propeller alloys, although of interest to DND, was originally undertaken at the request of the Canadian Coast Guard Service. Blades of ice-breaker propellers, sand cast in Mn-Ni-Al bronze, fractured in a brittle fashion, although specimens from separately cast test bars indicated it be should tough. The aims of the project are to identify the mechanisms responsible for the low fracture toughness of the sand-cast propellers and to recommend industrially-usable heat treatments to improve their impact toughness. The commercial foundry which casts the propellers - Canadian Stone Marine Ltd. - has cooperated with PMRL by allowing our staff to measure the rate at which propeller castings cool.

The situation affecting the high-damping propellers is slightly different. Here, the object is to minimize propeller noise detectable by underwater acoustical devices by using a propeller material of high damping capacity. 'Sonoston' is the name of a commercial alloy developed for this purpose. After discussions with DND, a project was initiated to evaluate the foundry characteristics of this alloy and to determine the effect of heat treatment on mechanical properties, and damping capacity.

PROPELLERS FOR ICEBREAKERS

In an attempt to develop an industrially practicable heat treatment that would improve the impact toughness of sand-cast Mn-Ni-Al bronze propellers, a series of low temperature (300 to 600°C) aging treatments were given to specimens cut from a propeller and the resulting hardness, magnetic permeability, microstructure and impact properties were determined. In addition, continuously cast Mn-Ni-Al bronzes containing 4-14% Mn are being heat treated to simulate microstructures representative of heavy sections in sand castings, such as those found in ice-breaker propellers.

Fatigue-crack growth rate studies in standard laboratory specimens of Ni-Al bronze alloys are being completed in air and salt water. Similar studies are being carried out on Mn-Ni-Al bronzes at Ecole Polytechnique, Montreal, on behalf of PMRL.

HIGH-DAMPING PROPELLERS

Preliminary studies were carried out to establish the foundry characteristics and mechanical properties of the Sonoston (Mn-Cu-Al-Fe-Ni) alloy. Isochronal and isothermal heat treatments are being carried out to optimize the damping capacity and mechanical properties of these alloys. Specific damping capacity measurements will be made at the Whiteshell Nuclear Research Establishment, Pinawa, Manitoba.

370091 - COST RECOVERY IN METALS PROCESSING TECHNOLOGY
Project Leader - W.H. Erickson

Government, industry and the universities made substantial use of PMRL's casting, heat treatment, metal forming and nondestructive testing facilities on over a dozen ocassions in FY 1982/83. A wide range of work was performed of which examination of defective steel castings for a private company and swaging of cylinders for a university form two examples.

370092 - TRANSFER OF METAL PROCESSING TECHNOLOGY TO INDUSTRY

Project Leader - J.T. Jubb

The objective of this project is to maintain a continuing record of the transfer of technology from projects undertaken in the Metal Processing Technology sub-activity.

The Canadian foundry industry is kept informed of foundry-related research at the Physical Metallurgy Research Laboratories through periodic issues of the CANMET Foundry Newsletter. Two Newsletters were issued in 1982/83. Judging from the response of industry, the Newsletter continues to be a useful vehicle for the transfer of foundry technology.

380021 - CERTIFICATION OF NONDESTRUCTIVE TESTING PERSONNEL

Project Leader - V.L. Caron

E.R. White and M. Breton of the NDT Section, preparing an examination paper on a word processor for the certification of personnel in non-destructive testing.

The objective of this project is to certify non-destructive testing (NDT) personnel on a national basis.

The strong growth of NDT reflects national concerns for a) public safety through the need for structural integrity of engineering structures (nuclear plants, pipelines, etc.); b) product quality and liability; and c) conservation of resources. Increasingly, contracts specify that products must be inspected by NDT personnel certified to CGSB standards. The certification of qualified NDT personnel must be strictly controlled and be unaffected by adverse influences or pressures. In Canada, there is a general consensus of opinion that the certification of NDT personnel is a function best performed in the public sector.

The role of Certifying Agency has for many years been assumed by EMR on a cost recovery basis. An extensive network of regional test centres has been set up throughout Canada at various technological institutes, DND establishments and other institutions in order to ensure easy accessibility for the public. The examinations are both set and marked by the central authority, EMR, in order to maintain uniformity.

In the next fiscal year NDT personnel will be certified on a national level, the change from a two-level to a three-level system for certification will be continued and major certification tasks will be computerized.

PART B. ENERGY RESEARCH PROGRAM

PROJECTS

420501 - MATERIALS FOR TAR SANDS PROCESSING
Project Leader - A.W. Lui

The oil recovery from Canadian tar sand deposits involves two types of operations: a) surface mining followed by physical separation and b) in-situ recovery of oil from deep underground deposits through steam injection or partial burning in the presence of oxygen. Surface mining requires handling and transport of enormous quantities of materials which are abrasive and corrosive, thus presenting a problem of excessive wear on equipment . In situ recovery involves high temperature corrosion and erosion imposing extremely severe wear conditions on materials used in the downhole operation of production wells. Each type of operation requires selection of appropriate wear-resistant alloys to extend the life of equipment and thus to lower production costs.

Laboratory testing and evaluation of experimental data on wear resistance performance has been completed for various candidate materials suitable for tailings pipelines. The data demonstrate that the use of corrosion resistant alloys for transport of tailings would be more beneficial than the use of abrasion resistant steels because of the greater contribution by corrosion to the total wear rates. Experiments to evaluate the relative contributions of corrosion and erosion to total wear have led to the development of a mathematical model.

At present attention is being focused on high temperature/high pressure testing techniques for wear resistance evaluation of materials suitable for use in in situ oil recovery processes. In the forthcoming work plan, the emphasis is to consolidate laboratory data on the effect of temperature, pressure, salinity and gas composition associated with materials performance that car by related to environmental severity in downhole operation.

420502 - PRESSURE VESSELS
Project Leader - J.T. McGrath

The objectives of this project are linked with the need for processing plants for the hydrotreatment of tar sands and heavy oils, and the liquefaction and gasification of coal. Specific technologies for the fabrication and inspection of heavy-wall pressure vessels are being developed by in-house and contracted out activities. In addition, the problems associated with in service deterioration of pressure vessel materials are being investigated.

WELDING PROCESSES

The in-house work focused primarily on the evaluation of the mechanical properties and microstructure of weld overlays produced by the strip overlay submerged-arc process. Weld overlays comprising 309L with 308L or 347 stainless steel deposited on 2.25 Cr - 1 Mo steel plate have been studied.

The contract work related to weld processes can be summarized as follows:

a) Narrow-gap welding of Cr/Mo heavy section steels: The effect of gas composition in the narrow-gap metal inert gas (MIG) process and the application of flux-cored wire to narrow-gap welding are being investigated.
b) Fabrication of pressure vessel nozzles: The electroslag casting technique for the preparation of pressure vessel nozzles is being

evaluated. Nozzles prepared from 2.25 Cr - 1 Mo steel by electroslag casting have shown excellent strength and notch toughness properties.

c) Weld cracking in 2.25 Cr - 1 Mo steel: The factors affecting hydrogen cracking in heavy section welds are being studied. The effectiveness of low temperature post-weld heat treatment as a method for preventing weld cracking is being investigated.

NONDESTRUCTIVE EVALUATION

The in-house work on the assembly of an ultrasonic wave system for detection of defects in heavy section welds has continued. The previously developed system is being improved with particular respect to the capability of accurately sizing defects.

An acoustic emission system which will be used to detect defects during welding is being developed under contract. A system has been assembled which can recognize the formation of specific welding defects.

PROPERTIES OF PRESSURE VESSEL MATERIALS

The following work on the evaluation of the in-service performance of pressure vessel materials has been done in-house:

a) Rare earth additions: Rare earth additions were found to improve the resistance to temper embrittlement of 2.25 Cr - 1 Mo steel. Large additions of rare earth elements significantly reduce the upper shelf CVN energy.

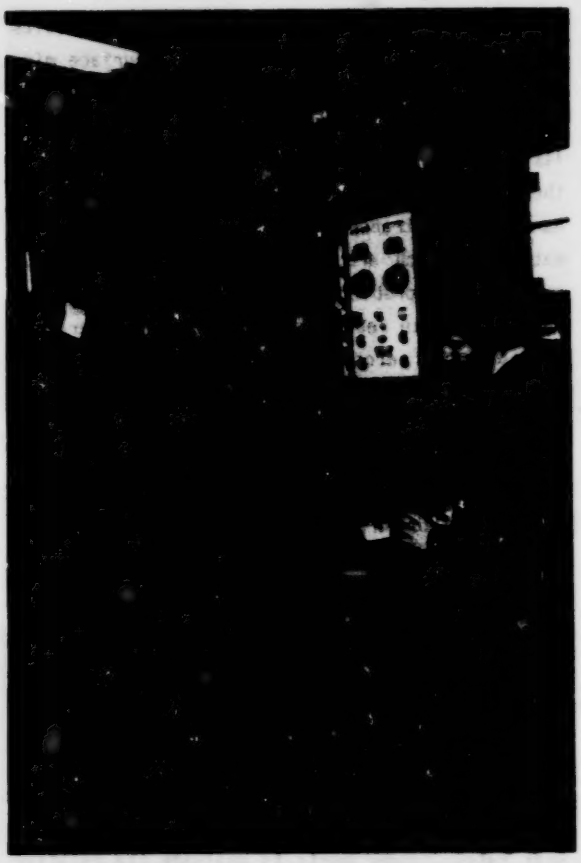
b) Stainless steel microstructures: A quantitative metallographic study using the Quantimet 900 image analyser, was able to identify the amount of ferrite, sigma and chi phases in type 316 stainless steel following simulated stress relief heat treatments

c) Hydrogen embrittlement: Stainless steel overlay on 2.25 Cr - 1 Mo base metal was subjected to high pressure, high temperature hydrogen in an autoclave. The effects of hydrogen on embrittlement in the weld overlay and on the susceptibility to disbonding between the overlay and the base metals are being investigated.

An external contract is examining the applicability of fracture mechanics to the control of creep-crack growth in pressure-vessel steels.

420503 - WELDING PROCESS DEVELOPMENT

Project Leader - J.T. McGrath



R. Orr of the Welding Section, setting up a submerged-arc narrow-gap welding system for experimental welding of a thick section of a pressure vessel steel.

The prime objective of this project is to develop the technology for the in-shop welding of heavy-section pressure-vessel steels. The major portion of the work is being carried out in two con-

tracts. Both contractors are assembling narrow-gap-welding systems which will have the capability of joining Cr/Mo steels with thicknesses of the order of 150 mm. The welds produced must meet specified requirements of quality and mechanical properties.

A submerged-arc narrow-gap-welding system has been assembled as part of the in-house program. Weld procedures will be developed to provide welds with optimum structural and mechanical properties.

420601 - DEVELOPMENT AND EVALUATION OF HIGH STRENGTH STEELS FOR OIL AND GAS PIPELINES

Project Leader - M.J. Godden

Earlier work on this project evaluated several sections of linepipe from different manufacturers. Whereas this evaluation of commercial linepipe is complete, the interpretation of the data continues to yield useful metallurgical insights. Recently, delamination frequency shown by Charpy tests in two modern Grade 483 linepipe steels has been correlated with shelf energy and shown to be a maximum in the transition between cleavage and ductile fracture. Studies of the micromechanisms of cleavage in these steels indicate that fracture initiates at the bands of non-polygonal phases and propagages along the interfaces between these phases and the polygonal ferrite phases.

The development of HSLA steels is an on-going process with a continuous trend towards higher strength, leaner alloy chemistries, thicker gauges and lower processing temperatures. An examination of possible routes to follow in the production of linepipe with a higher strength than Grade 483 but of similar or superior toughness and weldability has been initiated in order to support the Canadian pipemaking industry. Work has just started on the effect of accelerated cooling on the mechanical properties of a Canadian HSLA steel. Trials have produced cooling rates in a quench tank that will adequately simulate those experienced during on-line accelerated cooling (OLAC). It is intended to install OLAC facilities on PMRL's experimental rolling mill at a later stage of this work.

The effect of controlled rolling on microstructure development has been studied in other work. A series of rolling experiments was conducted to study the effects of a range of roughing reduction practices, combined with a fixed finish rolling schedule, on austenite recrystallization and final microstructure in a simple Nb-base composition. Microstructures were examined on samples quenched from reheat and from the early and end stages of roughing. Similar austenite grain sizes at the completion of roughing were attributable to partial recrystallization and the accumulation of strain during light reductions.

In allied work, a research contract with McGill University primarily investigates the effects of microalloying additions of Ti in linepipe steels to determine the kinetics of recrystallization and precipitation under static and dynamic conditions. The research to date has determined the dynamic recrystallization and precipitation kinetics in the austenite phase of a 0.1 wt% Ti steel with Mn contents of 0.5 - 1.5%. The study of kinetics continues on steels with 1.5% Mn and a range of Ti between 0.05 - 0.25%. Static recrystallization effects of Nb, V, and Mo were determined in an earlier part of this work.

In another part of this project, the need to understand the separate and synergistic effects of alloying additions is recognized. The study on the effects of Cr and V separately and together on a simple Nb-base composition is largely complete. Mill operating data and mechanical properties showed that additions of up to 0.11% V and 0.31% Cr had little influence on the roll-separating forces and final plate properties. Continuous-cooling transformation diagrams developed by dilatometry confirmed that V and Cr had little effect on ferrite formation, although both elements did act to suppress pearlite formation.

The distribution and chemical composition of precipitates in typical HSLA steels containing Nb

and/or Ti are being characterized by high resolution (STEM) electron microscopy under a contract with McMaster University. The process stages of the as-cast, as-soaked, as-rolled and welded (HAZ) steels are being studied. Earlier work concentrated on the partitioning of Nb and Ti in the fine carbonitrides, while currently, energy loss spectroscopy is being applied to determine C and N partitioning. The large-scale precipitate distribution is being characterized metallographically and the results will be compared with a model of the solidification path.

420602 - DEGRADATION, INSPECTION AND REPAIR OF PIPELINES

Project Leader - M.J. Godden

E.D. Smith and K.C. Wang of the Engineering and Metal Physics Section, examining crack initiation in a gouge in linepipe after pressure testing, in a study to determine the effects of accidental damage during installation on subsequent pipe performance.

As the pipeline network in Canada extends into more remote regions, the hazard of premature failure becomes increasingly important particularly because of the high financial costs likely to be incurred in repair. Many new wells being exploited are sour which can result in increased pipeline attack. The research being done attempts to address the main controllable pipeline failure mechanisms; mechanical damage during installation or during service, the several electrochemical degradation mechanisms and mechanical overload because of lack of subsoil support.

MECHANICAL DAMAGE

Mechanical damage in the form of dents and gouges can be produced in pipe during pipelaying by rocks and debris in the trench or by earth moving equipment. Research is being done on the failure mechanisms which operate as a result of the damage and the degree to which it can be tolerated. Both flattened specimens from linepipe materials and actual pipe specimens are being studied.

An elastic-plastic analysis of the stress state of a pipe with a dent has been completed. The plastic collapse failure mode of flattened specimens containing machined, pressed or gouged notches has been studied both experimentally and analytically. The effective stress-strain relationship has been applied to determine the maximum nominal stress for these specimens. The analytical predictions are consistent with the experimental results. Pipe specimens with gouged notches have been pressure tested. Preliminary results indicate that the present acceptance standards are safe but quite conservative.

RESIDUAL STRESS

Stresses in a pipeline can change because of earth settlement caused by washouts or by frost heave. In extreme cases, a pipe can be plastically deformed. Monitoring stress changes during the life of a pipeline gives the opportunity of pinpointing problem areas before failure occurs. This is particularly important in remote areas where earth movements are often not noticed and environmental damage is potentially serious.

CANMET and NRC/IMRI are jointly sponsoring research at Queen's University to correlate magnetic measurements in pipe with stress level. Parameters describing the magnetic hysteresis loop have been developed. The effects of stress on these parameters is being studied both experimentally and theoretically. Initial results on a Grade 414

linepipe steel indicate that within the range of stresses studied, the change in flux density was approximately proportional to the applied stress and there was no Villari reversal. Work has now begun on a Grade 483 linepipe steel.

CORROSION DEGRADATION MECHANISMS

Pipelines are subject to two types of electrochemical attack during service that subsequently lead to failure. Internal attack by hydrogen can occur in pipes transmitting wet H_2S-containing (sour) oil or gas. External attack from soil-borne mild corrodents can occur in "holidays" in the external pipeline coating. As more sour wells are exploited, the first failure mode will become increasingly important. Awareness of the problem has led to a collective initiative from industry resulting in share-funded research at PMRL.

Two forms of H_2S-induced cracking are under investigation, i.e. sulphide stress cracking (SSC) and stepwise cracking (SWC), in nine pipes covering Grades 290 to 483. The evaluation by standard methods is largely complete and attention has turned to other test methods and to determining the operative cracking mechanisms. Currently, the effects of stress and temperature on SWC are under investigation. The type and distribution of characterized inclusions will be measured in nine steels and attempts made to correlate with SWC and SSC behaviour.

Stress corrosion cracking (SCC) from external attack by soil-borne ions is another failure mechanism, particularly in older pipelines with poor coatings. Crack initiation and propagation during slow strain-rate SCC testing on a Grade 483 linepipe steel in a CO_3/HCO_3 environment has been investigated by a metallographic method. Crack initiation was found to be associated with pits, which act as stress concentrators. Comparison of SCC susceptibility for Grades 359 and 483 linepipe steel is being carried out at present. Development has begun on a new stressed-electrode cell for in-situ microscopy of tensile samples fractured by slow-strain rate testing.

420603 - FABRICATION OF PIPELINES
Project Leader - M.J. Godden

The assessment of the properties of mill welds in commercial linepipe and the field weldability of these steels has been completed. The results on seam weld metal toughness were interpreted in terms of the observed microstructural features. The examination of toughness in the coarse-grained heat-affected zone (CGHAZ) of the seam weld of commercial linepipe also concluded with observations on the value of the instrumented impact test for this work and deductions on the significance of critical flaw sizes in HAZ's.

The emphasis in this project in the past year has been directed towards overcoming the problem of reliably producing large-diameter linepipe fittings to Grade 414 and above. In particular the objective is to improve the strength and toughness of the seam weld. Submerged-arc welds were prepared in two commercial A633 Grade E steels using two wire/flux consumable combinations. The welds were normalized and stress relieved following welding. Only one of the wire/flux consumables provided sufficient strength and ductility in the weld metal. Neither wire/flux consumable combination provided welds with the required notch toughness of 40J at -50°C. Future work will concentrate on improving the notch toughness in welds of fittings using a quenching and tempering procedure.

Earlier work showed the difficulty of predicting CGHAZ toughness from easily-measured microstructural features. A contract will start shortly to study the important metallurgical factors contributing to the toughness of this region.

420604 - MATERIALS FOR OFFSHORE STRUCTURES
420606 - STRUCTURAL INTEGRITY MONITORING OF OFFSHORE STRUCTURES
420605 - COST-SHARED INDUSTRIAL PROGRAM ON STEELS FOR OFFSHORE STRUCTURES
Project Leader - R. Thomson

Because of their interlocking activities, these three projects will be dealt with jointly. The

in-house research activity has focused on precipitation effects on strength and toughness in Ti-N steels; on the effect of sea water temperature on corrosion fatigue; and on the development of a program on the fracture toughness of welded joints. The work on strengthening mechanisms in high-strength low-alloy steel for linepipe applications has provided a starting point for the detailed evaluation of the grain-boundary pinning of austenite by TiN particles. Two key pieces of equipment have been commissioned: a programmable quench-dilatometer with hot deformation capability, and a TEM/STEM microscope. Ongoing research has suggested that the process of stabilization of a fine equiaxed austenitic grain structure by TiN particles in microalloyed steel plate can be affected by other alloy components. There is some evidence that vanadium enhances the grain refining effect, and that niobium reduces the effect by complexing with TiN to form larger particles with a reduced restraint of grain boundary migration.

An experimental program on the effect of sea water temperature on corrosion fatigue crack-growth rates in structural steel has been completed. The results have demonstrated that the enhancement of fatigue crack-growth rate by corrosion decreases with decreasing temperature in the range 25°C to 0°C. At 0°C the observed growth rates in sea water are of the same order as those measured in air; at 25°C, however, sea water can increase the crack growth rate by a factor of five. A new laboratory for corrosion fatigue testing of thick plate welded T joints has been established, providing three separate test frames and related control instrumentation. The facilities will be utilized in an established test program on CSA grade 40.21 steel plate to be conducted in cooperation with industry. In related contract work at Memorial University, the effect of cold sea water and weld-toe grinding on the corrosion fatigue of a tubular monopod structure - a column supported by three equi-spaced angled braces - has been examined. The monopod welded joints displayed shorter fatigue lives than comparable simple T joints, and the cold sea water did not cause a thickness. The program represents an initial evaluation of present domestic capability to produce steel for welded structures displaying fracture toughness characteristics equivalent to Charpy V-notch values of 40 J at -60°C. Other aspects that are being evaluated include the formability of these particular steels in tubular joint manufacture; the mechanized flux-cored welding system for on-site fabrication; and methods for ultrasonic inspection of large girth welds.

430901 - MATERIALS FOR COAL HANDLING AND UTILIZATION

Project Leader - A.W. Lui

In line with the Federal Government "Off Oil" energy policy, Nova Scotia Power Corporation (NSPC) under the instruction of their provincial government is to establish a full-scale, coal-fired fluidized-bed-combustion facility for electricity generation. An assessment of the technical problems in such an undertaking revealed that one of the greatest concerns is the capability of in-bed heat-exchanger materials to survive 15-25 years of service. A one metre square fluidized-bed-combustion facility funded by EMR and dedicated to materials testing is to be constructed at Point Tupper, N.S., and PMRL is to perform the materials evaluation. During the FY 1982/83, PMRL expressed its views on materials testing requirements including the positioning of samples in a fluidized-bed combustor, exposure duration and temperature ranges, design of specimen probes and the monitoring of oxygen potential in the bed. In addition to in-bed and splash zone specimens, water cooled tubes and convective pass erosion probes will also be tested. The design of the probes and their exposure matrix have been finalized and work is progressing well.

An in-house research element directed toward an understanding of the mechanism of corrosion of boiler materials is underway. During the period of review, a thermogravimetric system was installed in the laboratory to follow the reaction kinetics of four Fe-Cr alloys in gas mixtures en-

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significant reduction in fatigue life at free corrosion potential. No improvement in fatigue life was achieved by weld-toe grinding. These various fatigue tests have been supported by theoretical work on the use of finite element methods (FEM) to perform global and local stress analyses in the complex joint geometries of offshore structures. The F.E. method has been used to determine stress intensity factors for two-dimensional weld-toe cracks in plate T joints. The analysis had the facility to input variable weld shapes.

Work on the identification of welding consumable and process variables to produce fracture tough weldments at -50°C was initiated late in FY 1982/83, and complements aspects of the cost-shared industrial research referred to below. Likewise, a new project on the effects of residual stress on fatigue crack propagation in or adjacent to weld deposits will contribute to the objectives of the corrosion fatigue work. It has been shown that residual stresses affect fatigue crack propagation rates and can be accurately accounted for using a fracture mechanics analysis when the residual stress source is remote from the crack tip. The residual stress fields across welds of T-joint configurations are being examined by conventional strain gauge and X-ray stress analysis techniques.

In the area of structural integrity monitoring (NDE testing), progress has been made toward creating an R&D activity on underwater NDE technology for the Eastern Canadian coast. A review of the subject area has indicated that ultrasonic test methods may be the most suitable for both manual and remote inspection techniques.

In the cost-shared research program, four Canadian companies have initiated work on aspects of steel production, fabrication and testing technologies relevant to Arctic and offshore applications. The prototype production of approximately 600 tons of tough weldable plate to CSA Grade 350WT and Lloyds LT-60 specifications will be followed by the detailed characterization of the fracture toughness and weldability of plate 15 to 100 mm in

countered in fluidized-bed combustion over a temperature range of 700° - 900°C. In flowing gas environments, and in the absence of ash deposit on the metal surface, linear kinetics with predominant oxidation of metal was always observed. When the metal surfaces were covered with calcium deposits, in the form of calcium oxide or calcium sulphate, the reaction rate increased and the increase varied with the amount of applied deposit and the operating temperature.

Coal-liquid fuel handling and utilization also falls under this project. During FY 1982/83, an R & D contract on the development of an erosion test for characterization of coal/water liquid fuel was undertaken. The apparatus for this work has been designed, constructed and tested. Now that the preliminary testing is complete, measurements on erosion of target materials and characterization of coal have commenced.

430902 - MATERIALS FOR HIGH-TEMPERATURE ENERGY CONVERSION PROCESSES

Project Leader - A.W. Lui

The purpose of this project is to develop solutions through applied research and development to a series of materials problems identified as potential inhibiting factors in high temperature energy systems. In the second year of this NEP project, two in-house support research elements were initiated to supplement the external R & D contracts undertaken during the FY 1981/82. The activities can be summarized as follows.

R & D CONTRACTS

1. Chemical vapor deposited coating for high temperature corrosion resistance.
   A plasma vapor deposition coating of TiB_2 was developed, but the adhesion to the metal substrate was not satisfactory. The rate of coating deposition, the rate of specimen cooling and the geometrical configuration of specimen to be coated were investigated in an attempt to improve the situation. Coated specimens are now being evaluated at PMRL by hot corrosion testing and by exposure to gases containing sulphur dioxide.

2. Design and construction of a high temperature erosion test facility.
   Phase I of the contract to design the unit has been completed including modifications that were necessary to improve performance in the laboratory. The construction phase (Phase II) has just started. Once the unit is complete, experiments will be performed to study erosion properties of alloy steel in support of the fluidized-bed combustion project (Phase III).

3. Stress-rupture properties of materials in coal conversion systems.
   The purpose of this contract was to evaluate the effects of simulated fluidized-bed-coal combustion on the stress-rupture properties of heat exchanger tube materials. Stress-rupture curves have been determined for stainless steels Type 310 and 347H. Incoloy 800H and alloy HK40 for times of approximately 1000h in a simulated fluidized-bed coal-combustion environment of low oxygen and high sulphur potential.

IN-HOUSE RESEARCH

A research element that addresses potential high temperature corrosion problems was initiated. The work includes characterization of Nova Scotia limestones and their influence on alloy corrosion in the fluidized-bed combustion of coal. Development of alloys that will resist high temperature oxidation under cyclic conditions will also be investigated.

The second in-house project is the study of sulphate corrosion of metals and the formation of pseudo-scale deposits. The thermoanalyzer for use on this project was acquired in late December and has just become operational.

PART C. PUBLICATIONS, PRESENTATIONS AND REPORTS

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Shehata, M.T., Lavigne, M.J.A. and Boyd, J.D. "Quantitative metallographic study of ferrite to sigma transformation in Type 316 stainless steel"; 15th Annual Technical Meeting of the International Metallographic Society, Orlando, Fla., July, 1982.

Shehata, M.T. "Image analysis - applications in metallurgy"; Ottawa Valley Electron Beam Group, Spring Seminar, Ottawa, Ont., May 26, 1982.

Shehata, M.T. and **Boyd, J.D.** "Automatic image analysis in microstructural characterization"; TMS-AIME Annual Meeting, Atlanta, Ga., March 7-9, 1983.

Tyson, W.R. "Dynamic toughness"; Workshop, PMRL, Ottawa, Ont., September, 1982.

Tyson, W.R. and Bala, S.R. "Dynamic toughness and cold formability of steel plate"; 6th Symposium on Eng Appl of Mech, Calgary, Alta., June, 1982.

Tyson, W.R. "Designing better materials: Dual-phase steels"; Carleton University, Ottawa, Ont., February, 1982.

Tyson, W.R., Boyd, J.D. and McGrath, J.T. "Effect of inclusions on dynamic toughness of line-pipe steel"; Symposium on Defects Fractured Fatigue, Mont Gabriel, Que., June 1, 1982.

Vosikovsky, O. "Corrosion fatigue life of a sour crude oil pipeline"; Underwater Technology Conference, Bergen, Norway, April, 1982.

Warda, R.D. and Whiting, L.V. "Statistical process control using microcomputers"; Computer Applications Seminar, Wisconsin Regional AFS Conference, Milwaukee, Wis., February 9, 1983.

Warda, R.D. "Cupolas, computers and controls"; Annual Awards Banquet, Pennsylvania State Chapter of the Foundry Education Foundation, State College, Pa., October 28, 1982.

Warda, R.D. "Cupolas, controls and computers"; Joint meeting of the Ontario and Western New York State Chapters of the Am Foundrymen's Soc., Buffalo, N.Y., November 5, 1982.

Warda, R.D. "Using microcomputers to analyze and control cupola operations"; oral presentation to staff and students, Department of Industrial Engineering, Penn State University, State College, Pa, October 26, 1982.

Warda, R.D. and Whiting L.V. "Using microcomputers to control processes, quality and costs in the foundry"; Seminar on Computer Applications in the Foundry Industry, Mohawk College, Hamilton, Ont., February 24-25, 1983.

Warda, R.D. and Whiting, L.V. "Cupola trouble shooting with microcomputers"; Gray Iron Research Institute Workshop on Cupola Operations, Cleveland, Ohio, March 22-23, 1983.

AVAILABLE PMRL REPORTS

ERP/PMRL 80-89(R) Gilmour, J.B. "Some effects of hydrogen on the steel used in the Laprade Heavy Water Plant".

MRP/PMRL 81-74(IR) McDonald, R.D. and Harbec, J. "Examination of cracked plates from the hull and bilge keel of the tanker "Irving Esk[illegible]".

MRP/PMRL 81-79(IR) Davis, K.G. "New foundry techniques".

MRP/PMRL 82-27(IR) Davis, K.G. and Magny, J.G. "Carbon steel billets cast around stainless steel cores".

MRP/ERP/PMRL 82-40(IR) Dixon, C. "PMRL - Metal research activities".

MRP/PMRL 81-17(TR) Parsons, D.E., Munro, B.A. and Ng-Yellin, J. "Sectioning tests on Sysco/CNR Cr-Cb premium rail".

ERP/PMRL 81-19(TR) **McGrath, J.T.** "Evaluation of the HAZ toughness of pipe AE seam weld".

MRP/PMRL 81-27(TR) **Fegredo, D.M.** and **Connors, E.F.** "Progress report on the resistance to wear of selected commercial and experimental steels in collaboration with Dr. J. Kalousek".

MRP/PMRL 81-39(TR) **Biefer, G.J., Fichera, M.** and **Selugn, J.** "Stepwise cracking tests of line pipe in H_2S environments".

MRP/PMRL 81-46(TR) **McDonald, R.D.** and **Ramsingh, R.R.** "Corrosion tests by the under-car method, December 1978 to May 1980".

MRP/PMRL 81-63(TR) **Knight, R.F.** "Mechanical properties of experimental direct-quenched steels and commercial abrasion-resistant plate".

MRP/PMRL 81-67(TR) **Sahoo, M., Barry, J.R.** and **Kleinschmidt, K.** "High-strength copper base alloys for shipboard systems: Nickel-aluminum bronze alloys. Progress report NAB-9, July 1, 1980 to September 30, 1981".

ERP/PMRL 81-75(TR) **Orr, R.F., Letts, M.W., Harraway, R.** and **McGrath, J.T.** "Welding procedure and evaluation of mechanical properties of a heavy section 2.25 Cr - 1 Mo steel weldment".

MRP/PMRL 81-80(TR) **McDonald, R.D.** and **Ramsingh, R.R.** "The use of inhibitors to reduce the corrosion of automotive steels in a chloride environment".

ERP/PMRL 81-81(TR) **McDonald, R.D.** and **Letts, M.W.** "Weldability of line-pipe steels AG".

MRP/PMRL 82-8(TR) **Godden, M.J.** "The effect of some factors on particles sizes in line-pipe steels containing titanium".

MRP/PMRL 82-9(TR) **Lagowski, B.** "Filters in the gating system for magnesium and aluminum castings".

MRP/PMRL 82-14(TR) **McGrath, J.T.** "Notch toughness of the HAZ of pipe AG seam weld".

MRP/PMRL 82-15F(TR) **Davis, K.G., Boisjoly, R., Magny, J.G.** and **Ng-Yelim, J.** "Traitement thermique intercritique d'un acier moulé type 'LCC'".

ERP/PMRL 82-17(TR) **Lui, A.W.** and **McGoey, J.** "Evaluation of CVD coating developed at ORF for use in fossil energy conversion system I-TiB_2 on carbon steel".

MRP/PMRL 82-28(TR) **Ruddle, G.E., Milliken, K.S., Smelsky, G.M.** and **Crawley, A.F.** "Progress report on automatic control of the CANMET 457 mm mill".

MRP/PMRL 82-30(TR) **McGrath, J.T.** "Some factors affecting heat-affected zone toughness in titanium bearing steels".

MRP/PMRL 82-31(TR) **Davis, K.G.** "The production and field testing of Cancoat Dragger Shoes".

MRP/ERP/PMRL 82-39(TR) **Erickson, W.H., White, D.W.G.** and **Jubb, J.T.** "PMRL Annual Report FY 1981-1982".

MRP/PMRL 82-44(TR) **Sahoo, M.** "High-strength cast nickel-aluminum bronzes".

ERP/PMRL 82-52(TR) **Neill, W.R.** "A computer-controlled system for measuring fatigue crack growth".

MRP/PMRL 82-55(TR) **Baragar, D.L.** "CAM plastometer: Operational status and plans for upgrading".

ERP/PMRL 82-75(TR) **Too, J.J.M.** "A mathematical formulation for the analysis of 3-roll metal forming processes".

ERP/PMRL 81-13(J) **Knight, R.F., Tyson, W.R., Lavigne, M.J.A., McGrath, J.T.** and **Boyd, J.D.** "Material for hydrogenation vessels".

ERP/PMRL 81-23(J) **Bell, D.R., Casault, B.** and **Boyd, J.D.** "A metallurgical evaluation of 3 types of grade 483 line pipe".

ERP/PMRL 81-33(J) **Cheng, J.M., Embury, J.D., Shehata, M.T., Boyd, J.D.** and **McCutcheon, D.B.** "The influence of rolling practice on fracture properties of hot-rolled plate".

MRP/PMRL 81-57(J) **Fegredo, D.M., Pollard, W.A., Connors, E.** and **Kiff, D.** "End-quench screening experiments and the application of the results in the controlled cooling of hot-rolled plates of potential rail-steel compositions".

MRP/PMRL 81-73(J) **Crawley, A.F., Ruddle, G.E.** and **Shehata, M.T.** "Microstructures, properties and rolling mill requirements for some as-hot-rolled dual-phase steels".

ERP/PMRL 82-12(J) **Biefer, G.J., Fichera, M.** and **Selwyn, J.** "Stepwise cracking behaviour of some Canadian line pipes".

ERP/PMRL 82-21(J) **Revie, R.W.** and **Ramsingh, R.R.** "Effects of potential on stress-corrosion cracking of grade 483 (X-70) HSLA line-pipe steels".

ERP/PMRL 82-24(J) **Hoey, G.R.** and **Bednar, J.S.** "Erosion/corrosion of selected metals in coal-washing-plant environments".

MRP/PMRL 82-36(J) **Vosikovsky, O., Macecek, M.** and **Ross, D.J.** "Allowable defect sizes in a sour crude oil pipeline for corrosion fatigue conditions".

MRP/PMRL 82-46(J) **Packwood, R.H.** and **Brown, J.D.** "A new theory for microprobe analysis".

MRP/PMRL 82-50(J) **Moore, V.E., Fegredo, D.M.** and **Packwood, R.H.** "The examination of martensite streaks for Mo segregation".

ERP/PMRL 82-51(J) **Sastri, V.S.** "Spectral studies on some novel oxygen scavengers".

MRP/PMRL 82-53(J) **Sahoo, M., Edwards, J.O.** and **Couture, A.** "Forty years of investigation, research and technology development on copper based alloys at PMRL".

MRP/PMRL 82-54(J) **McGrath, J.T.** and **Godden, M.J.** "HAZ fracture toughness evaluation of linepipe welds".

ERP/PMRL 82-58(J) **Tyson, W.R.** "Fracture control: Current issues".

MRP/PMRL 82-63(J) **Ruddle, G.E., Milliken, K.S., Smelsky, G.** and **Crawley, A.F.** "A pilot-scale rolling mill for process and material development".

MRP/PMRL 82-67(J) **Brigham, R.J. and Marvan, I.J.** "Further observations on the variability of crevice corrosion initiation in ferric-chloride exposure tests".

MRP/PMRL 82-68(J) **Fegredo, D.M. and Laufer, E.E.** "A quantitative electron microscopic examination of Nb- and V (C,N) precipitates in eutectoid premium rails steels transformed under various conditions.".

MRP/PMRL 82-69(J) **Shehata, M.T. and Crawley, A.F** "Microstructure property relationship in batch annealed C-Mn dual-phase steels".

MRP/PMRL 82-82(J) **Warda, R.D. and Whiting, L.V.** "CANMET uses microcomputers to transfer foundry technology".

MRP/PMRL 82-16(OP) **Davis, K.G.** "Intercritical heat-treatment of cast steels".

MRP/PMRL 82-22(OP) **Pollard, W.A., Desabrais, F.S and Crawley, A.F.,** "On-line heat-treatment of forged & rolled steel shapes in fluidized beds".

MRP/PMRL 81-6(OP-J) **Crawley, A.F., Shehata, M.T. Pussegoda, N., Mitchell, C.M. and Tyson, W.R.** "Batch-annealed dual-phase steels".

ERP/PMRL 81-53(OP-J) **Shehata, M.T. and Boyd, J.D** "Quantitative correlations between toughness and microstructure for commercial line-pipe steel".

MRP/PMRL 81-83(OP-J) **Sahoo, M.** "Weldability of nickel-aluminum bronze alloy C95800".

MRP/PMRL 82-1(OP-J) **Malis, T. and Chaturvedi, M.** "Variations in grain boundary segregation for Al-8 Mg".

MRP/PMRL 82-7(OP-J) **Vosikovsky, O.** "Corrosion fatigue life of a sour crude oil pipeline".

ERP/PMRL 82-10(OP-J) **Tyson, W.R. and Bala, S.R.** "Dynamic toughness and cold formability of steel".

MRP/PMRL 82-13(OP-J) **Crawley, A.F. and Shehata, M.T.** "Ductility, strength and microstructural effects of simulated in-line galvanizing of continuous annealed dual-phase steels".

MRP/PMRL 82-20(OP-J) **Sahoo, M.** "Structure and mechanical properties of slow-cooled nickel-aluminum bronze alloy C95800".

MRP/PMRL 82-26(OP-J) **Sastri, V.S.** "Review of the methods for the determination of hydrogen in steels".

ERP/PMRL 82-35(OP-J) **Tyson, W.R., Boyd, J.D. and McGrath, J.T.** "Effect of inclusions on dynamic toughness of line-pipe steel".

MRP/PMRL 82-38(OP-J) **Mshana, J.S., Vosikovsky, O. and Sahoo, M.** "Corrosion fatigue behaviour of nickel-aluminum bronze alloys".

ERP/PMRL 82-48(OP-J) **Shehata, M.T., Lavigne, M.J. and Boyd, J.D.** "Quantitative metallographic study of ferrite to sigma transformation in type 316 stainless steel".

MRP/PMRL 82-61(OP-J) **Sahoo, M., Edwards, J.O., Szanto, Z. and Beke, L.J.** "Production of a six-valve chest casting in Nb-modified 70/30 Cu-Ni alloy (C96400)".

MRP/PMRL 83-2(OP-J) **Davis, K.G., Magny, J.G. and Zaino, G.** "Intercritical heat-treatment of cast steels".

MRP/PMRL 83-3(OP-J) **Bukr, R.K. and Nilmani, M.** "The electroslag process for casting production".

MRP/PMRL 83-8(OP-J) **Packwood, R.H., Broun, J.D. and Ramond, G.** "$\phi(\rho z)$".

INTERNAL AND CONFIDENTIAL REPORTS

(not for inclusion in the open file)

ERP/PMRL 81-48(INT) **Saiddington, J.C.** "Evaluation of corrosion and erosive wear rates from differences of rate variation with test velocities".

ERP/PMRL 81-59(INT) **Saiddington, J.C. and Psutka, M.A.** "Corrosive and abrasive wear of selected materials in tar sand tailings slurries".

MRP/PMRL 82-4(INT) **Eastman, K.** "Electroslag casting progress report".

MRP/PMRL 82-5(INT) **Boyd, J.D.** "Bibliography of publications, reports and oral presentations by the Ferrous Metal Section (1975 - 1979) and the Metallurgy Section (1980 -)".

MRP/PMRL 82-18(INT) **Bukr, R.K., Eastman, K. and Nilmani, M.** "Electroslag casting progress report no. 2".

ERP/PMRL 82-19(INT) **Cousineau, E.J. and Mitchell, C.M.** "Phase identification in 316 stainless steel by X-ray diffraction".

ERP/PMRL 82-34(INT) **Bell, R.** "Preliminary investigation of the stress intensity factor at shallow weld toe cracks".

ERP/PMRL 82-45(INT) **Munro, D.A., Moore, V.E. and Parsons, D.E.** "Examination of type 304 stainless steel oil nozzle".

MRP/PMRL 82-62(INT) **Cousineau, E.J. and Mitchell, C.M.** "Determination of retained austenite in a steel casting".

MRP/PMRL 82-65(INT) **Chartrand, V.** "SEM examination of failed rock bolt samples".

ERP/PMRL 82-66(INT) **Casault, B.R.** "Advanced techniques in optical metallography".

MRP/PMRL 82-77(INT) **Nilmani, M., Bukr, R.K. and Mitchell, A.** "Electroslag casting using wire-electrodes".

MRP/PMRL 82-78(INT) **Bukr, R.K. and Nilmani, M.** "The production of aluminum-moulds with cored cooling channels for electroslag casting".

ERP/PMRL 83-2(INT) **Braid, J.E.M.** "Materials for offshore structures".

MRP/PMRL 81-16(CF) **Mitchell, C.M., Cousineau, E.J. and Fryzuk, P.** "Measurement of surface and sub-surface deformation in magnesium AZ92 alloy castings".

MRP/PMRL 82-4(CF) **Knight, R.F.** "Examination of welded cold-formed steel sheet piling".

MRP/PMRL 82-5(CF) **Crawley, A.F., Ruddle, G.E.** and **Linkletter, D.E.** "Laboratory rolling of steels for Stelco Inc: Simulation of roughing sequence in hot-strip rolling".

MRP/PMRL 82-6(CF) **Dion, J.L.** "Examination of metal samples from the scene of a fire in St. Stephen, N.B.".

MRP/PMRL 82-7(CF) **Davis, K.G.** and **Magny, J.G.** "Examination of cracking under a riser in a casting of wear-resistant steel".

MRP/PMRL 82-8(CF) **Champagne, F.** "Ultrasonic thickness measurements of three oil tanks located at the Central Heating Plant at the National Research Council".

MRP/PMRL 82-9(CF) **Munro, D.A.** and **Parsons, D.E.** "Metallurgical examination of a super-heater hand--hole cover".

MRP/PMRL 82-10(CF) **Crawley, A.F, Webster, J.C.** and **Smelsky, G.** "Cold drawing of zirconium alloy tubes".

MRP/PMRL 82-12(CF) **Harbec, J.** "Evaluation of two propane cylinders".

MRP/PMRL 82-13(CF) **Parsons, D.E., Munro, D.A.** and **Knight, R.F.** "Metallurgical examination of samples from a propane tank car (CGTX-63712) after a derailment near Austin, Manitoba, January 10, 1982".

MRP/PMRL 82-14(CF) **Knight, R.F.** "Examination of broken wheel and brake beam from Car C.P. 316401".

MRP/PMRL 82-15(CF) **Knight, R.F.** "Examination of drum pilot valve actuators".

MRP/PMRL 82-16(CF) **Davis, K.G., Magny, J.G.** and **Moore, V.E.** "Scale defects on cored surfaces of ductile iron hydraulic valve casting".

MRP/PMRL 82-17(CF) **Parsons, D.E., Munro, D.A.** and **Knight, R.F.** "Examination of broken rails recovered after a derailment of CNR train 220 at mile 84.7, 'Rivers subdivision' Manitoba".

MRP/PMRL 82-18(CF) **Warda, R.D.** "Analysis of a rock-wool cupola operation".

MRP/PMRL 83-1(CF) **Sahoo, M., Seto, L., Kleinschmidt, K.** and **Moore, V.E.** "Examination of galvanized steel sheets".

REPORTS BY CATEGORY

Publications	29	Available PMRL Reports	66
Presentations	45	Internal and Confidential Reports	30

PART D. STAFF ACTIVITIES

1982-83 CONFERENCE ATTENDANCE

Biefer, G.J. 1982 Spring Meeting of the Electrochemical Society, Montreal, Que., May 9-11, 1982.

Boyd, J.D., Crawley, A.F., Davis, K.G., and Pollard, W.A. CIM 21st Conference of Metallurgists, Toronto, Ont., August 29 - September 1, 1982.

Boyd, J.D. TMS-AIME Annual Meeting, Atlanta, Ga., March 7-9, 1983.

Caron, V.L. Annual ACFAC Congress, Montreal, Que., May 11-14, 1982.

Carpenter, G.J.C. 10th International Congress on Electron Microscopy, Hamburg, West Germany, August 17-24, 1982.

Carpenter, G.J.C., Collins, L.E., Cousineau, E.J., Fegredo, D.M., Hindam, H.M., Malis, T., Mitchell, C.M., Ng-Yellm, J. and White, D.W.G. 32nd Canadian Metal Physics Conference, Kingston, Ont., June 22-25, 1982.

Chandel, R.S. International Conference on Welding Technology for Energy Applications, Knoxville, Tenn., May 16-20, 1982.

Crawley, A.F. Spring Meeting of the American Deep Drawing Research Group, Cleveland, Ohio, May 10-12, 1982.

Crawley, A.F. Fall Meeting of the American Deep Drawing Group, Alton, Ill., October 19-21, 1982.

Davis, K.G. 49th International Foundry Conference, Chicago, Ill., April 13-17, 1982.

Dion, J.L., Sahoo, M., Warda, R.D., and Whiting, L.V. AFS Casting Congress, Chicago, Ill., April 18-23, 1982.

Hindam, H.M. CNRG-IGM, Montreal, Que., September 1982.

Hindam, H.M. Japan Institute of Metals - 3rd International Symposium on High Temperature Corrosion of Metals, Tokyo, Japan, November 1982.

Hoey, G.R. 7th Annual Meeting of CIM District 4, Saskatoon, Sask., October 7-9, 1982.

Hoey, G.R. Canadian Eastern Region NACE Conference, Montreal, Que., November 23-25, 1982.

Lui, A.W. Conference on Corrosion in Coal Conversion Systems, London, England, May 3-15, 1982.

McDonald, R.D. 63rd Annual American Welding Society Conference and AWS Welding Show, Kansas City, Miss., April 25-29, 1982.

Malis, T. Electron Microscopy Society of America - Annual Meeting, Washington, D.C., August 8-13, 1982.

Mitchell, C.M. 31st Annual Conference on Applications of X-ray Analysis, Denver, Colo., August 3-7, 1982.

Monchalin, J.P. Advanced NDE Technology Conference, Montreal, Que., May 31-June 1, 1982.

Revie, R.W. Gordon Research Conference on Corrosion, New London, N.H., July 26-30, 1982.

Revie, R.W. Materials for Coal Conversion and Utilization - National Bureau of Standards, Gaithersburg, Md., November 16-18, 1982.

Ruddle, G.E. TMS-AIME Fall Meeting / ASM Metals Congress, St. Louis, Miss., October 25-27, 1982.

Shehata, M.T. 15th Annual Technical Meeting of the International Metallographic Society, Orlando, Fla., July 17-22, 1982.

Tyson, W.R. International Conference on Defects, Fracture and Fatigue, Mont Gabriel, Que., May 30-June 5, 1982.

Tyson, W.R. Sixth Symposium on Engineering Applications of Mechanics, Calgary, Alta., June 6-12, 1982.

Vosikovsky, O. Underwater Technology Conference, Bergen, Norway, April 1982.

FIELD TRIPS AND SIGNIFICANT MEETING TRAVEL

D.L. Baragar

Discussed thermomechanical treatment of steel at University of Pittsburg, Pittsburg, Penn., June 2-3, 1982.

G.J. Biefer

Discussed progress of joint funded work on H_2-induced linepipe cracking, Calgary, Alta., May 5, 1982.

J.T. Bouker

Attended meeting with Stelco research personnel, Toronto, Ont., November 23-24, 1982.

Attended training skills upgrading session on Gleeble 1500, Ogdensburg, N.Y., February 2, 1983.

J.D. Boyd

Visited McGill University to discuss hot deformation of steel, Montreal, Que., April 6, 1982.

Visited Stelco labs for discussions on Ti-N steels, Hamilton, Ont., May 1, 1982.

Visited Falconbridge Research Laboratories, Toronto, Ont., June 15, 1982.

Attended seminar on STEM at Ecole Polytechnique, Montreal, Que., July 19, 1982.

Visited Bethlehem Steel and Lehigh University to discuss use of TEM/STEM and dilatometry, Allentown, Pa., June 2-3, 1982.

Attended meeting of organizing committee for International Conference on HSLA Steels, Pittsburg, Pa., August 10, 1982.

Made presentation at Atlas Steel Limited, Welland, Ont., October 2-4, 1982.

Attended CIM meeting, Montreal, Que., December 3, 1982.

Attended meeting of CMQ, Toronto, Ont., February 10, 1983.

Attended meeting on HSLA steels, Pittsburg, Penn., February 11, 1983.

Made site visit to McMaster University for BILD program, Hamilton, Ont., February 17-18, 1983.

D.C. Briggs

Attended meeting of the Metal Properties Council, Subcommittee 9: Materials for Coal Conversion, Chicago, Ill., April 20-22, 1982.

Attended demonstration of the Buehler Maximet metallographic specimen preparation system, Toronto, Ont., June 16, 1982.

Visited the Petten Establishment of the Joint Research Centre for the Commission of European Communities for discussions on materials for coal conversion processes, Petten, The Netherlands, July 12, 1982.

Visited the Coal Research Establishment of the National Coal Board for discussions on materials for coal conversion processes, Cheltenham, U.K., July 22, 1982.

Discussed research projects at IMRI, Montreal, Que., September 15, 1982.

Consulted with Combustion Engineering concerning specimen probes for exposure in the NSPC fluidized-bed-coal combustor, Windsor, Conn., December 15, 1982.

Visited the Sherritt Research Centre for discussions on stress-rupture testing in corrosive environments, Fort Saskatchewan, Alta., March 15, 1983.

R.K. Buhr

Attended foundry workshop at Queen's University, Kingston, Ont., May 2-4, 1982.

Visited Falconbridge Research Laboratories, Toronto, Ont., June 15, 1982.

Visited Pfizer Canada Inc. to discuss Degradable Sand Binder project, Montreal, Que., June 16, 1982; October 14, 1982.

Visited Cleveland CAE Metal Abrasives Limited and CAE Welmet Industries Limited, Welland, Ont., July 19-20, 1982.

Attended meeting with Dofasco on Ladle Metallurgy, Hamilton, Ont., September 24, 1982.

Attended meeting of Ductile Iron Research Committee 12K, AFS, Des Plaines, Ill., October 4-5, 1982; March 7-8, 1983.

Visited Abex Corp., Joliette, Que., November 21-23, 1982.

Attended meeting with Canadian Steel Foundries, Montreal, Que., January 14, 1983.

V.L. Caron

Attended meeting of CSNDT Foundation Long Term Committee, Toronto, Ont., April 6, 1982.

Visited NDT certification practical test centre in Edmonton, Alta. Addressed the local CSNDT Chapter.

Attended workshop on advanced NDE Technology, Montreal, Que., May 30 - June 2, 1982.

Attended CSNDT Foundation Executive and Trustees meeting, Hamilton, Ont., June 17-18, 1982.

Visited IMRI-NRC to discuss R&D projects, Montreal, Que., August 6, 1982.

Lectured on and discussed NDT certification program with NDT personnel, CAF, Trenton, Ont., September 27, 1982.

Attended a demonstration and information session on high-technology NDT equipment, Montreal, Que., November 22, 1982.

Interviewed applicants for employment at PMRL, Montreal, Que., January 27, 1983.

Visited Laval University, Quebec City, Que., March 14-15, 1983.

Attended a meeting on ISO/TC135 to prepare for international meeting in Ottawa, Sept., 1983.

G.J.C. Carpenter

Visited Bell labs to discuss techniques for making TEM sections through microchips, Murray Hill, N.J., April 19-22, 1982.

Attended seminar on STEM at Ecole Polytechnique, Montreal, Que., July 19, 1982.

Attended training session on the operation of the Gatan EELS on the Philips EM 400T, Mahwah, N.J., January 19, 1983.

Attended course on Philips EM 400T Electron Microscope at Eindhöven, The Netherlands, and Bristol, U.K., February 16 - March 11, 1983.

B.R. Casault

Attended an intensive course on "Advanced Techniques in Optical Metallography", American Society for Metals, Metals Park, Cleveland, Ohio, September 27 - October 1, 1982.

F. Champagne

Attended demonstration of KB 6000 at IMRI, NRC, Montreal, Que., May 13, 1982.

L.E. Collins

Visited McGill University to discuss hot deformation of steel, Montreal, Que., April 6, 1982.

Visited Bethlehem Steel to discuss use of TEM/STEM and dilatometry, Allentown, Penn., June 2-3, 1982.

A.F. Crawley

Visited McMaster University to discuss contract progress, Hamilton, Ont., April 27, 1982.

Visited Stelco Research Centre to discuss cooperative research in controlled rolling of linepipe steels, Burlington, Ont., May 18, 1982.

Discussed contract on forging with R.E. Moore (Consultant), Welland, Ont., June 22, 1982.

Attended meeting of CIM Materials Engineering Committee as secretary, Toronto, Ont., October 7, 1982.

Interviewed co-op students, University of Waterloo, Waterloo, Ontario, February 24, 1983.

Visited Stelco R&D to discuss research topic in automotive sheet, Hamilton, Ontario, February 25, 1983.

Visited Dofasco R&D to discuss research topic in automotive sheet, Hamilton, Ont., February 25, 1983.

Visited McMaster University to discuss progress in contract on cold forgings and to discuss cooperative research on fluidized-bed technology, Hamilton, Ont., February 25, 1983.

K.G. Davis

Attended foundry workshop at Queen's University, Kingston, Ont., May 2-4, 1982.

Attended meeting at Dofasco on Ladle Metallurgy, Hamilton, Ont., September 24, 1982.

Visited Canadian Steel Foundries, Montreal, Que., December 17, 1982.

J.L. Dion

Appeared in court as expert witness, Fredericton, N.S., August 18-19, 1982.

B.A. Euser

Attended training course to become familiar with EDAX equipment, Chicago, Ill., March 21-25, 1983.

W.H. Erickson

Attended meeting of the Canadian Steel Industry Research Association Board of Directors, Montreal, Que., April 15-16, 1982.

Discussed proposed Canadian centre for arctic and offshore materials engineering, Calgary, Alta., May 3-4, 1982.

Discussed development of a cooperative research program with University of Montreal, Montreal, Que., May 11-13, 1982.

Visited Lake Erie Works and Stelco to view new steel plant and discuss continuous casting research, Hamilton, Ont., June 9, 1982.

Met with representatives of the European Coal and Steel community to discuss cooperative research, June 15, 1982.

Attended meeting of CSIRA Directors, Toronto, Ont., September 1-2, 1982.

Attended 14th meeting of WIC Council, Toronto, Ont., October 25-26, 1982.

Attended 4th annual general meeting of WIC, Toronto, Ont., November 30, 1982.

Discussed guidelines for Centre for Frontier Engineering Research, Calgary, Alta., December 7, 1982.

Attended Board of Trustee's meeting CSNDT, Toronto, Ont., January 21, 1983.

Attended meeting of WIC Council, Toronto, Ont., February 9, 1983.

B. Faucher

Visited PMRL, Ottawa, Ont., April 2, May 5, May 24-25, June 10, 1982.

Met with Professor Dickson of Ecole Polytechnique to discuss ductile rupture projects, Montreal, Que., July 26, 1982.

D.M. Fegredo

Gave seminar at Technical University of Nova Scotia, Halifax, N.S., June 10-11, 1982.

J.B. Gilmour

Met with engineers of Davie Shipbuilding to discuss materials problems of offshore structures, Quebec City, Que., May 20, 1982.

Met with representatives of the European Coal and Steel Community to discuss cooperation on materials research for offshore structures, Brussels, Belgium, June 15-19, 1982.

Discussed corrosion fatigue testing with University of Waterloo and WIC, Waterloo, Ont., June 21, 1982.

Discussed steels for offshore structures and arctic vessels with representatives of Canadian Steel Industry, Burlington, Ont., June 1982.

Discussed research projects at IMRI, Montreal, Que., September 15, 1982.

Attended a management committee meeting of EMR-NSPC fluidized-bed combustion project, Halifax, N.S., October 13-15, 1982.

Discussed marine and arctic corrosion with scientists of the Department of Fisheries and Oceans, Burlington, Ont., November 8, 1982.

Discussed project on fluidized-bed-coal combustion with Combustion Engineering, U.S.A., Windsor Conn., December 15, 1982.

M.J. Godden

Discussed progress of joint-funded work on H_2 — induced linepipe cracking, Calgary, Alta., May 4-5, 1982.

Visited Stelco Labs for discussion on Ti-N steels, Burlington, Ont., May 18, 1982.

Discussed proposed OLAC work for grade-80 linepipe with Stelco personnel, Burlington, Ont., October 27-28, 1982.

H.P. Guindon

Visited University of Toronto to arrange demonstration of horizontal concasting, Toronto, Ont., March 28, 1983.

H.M. Hindam

Reported to PMRL and discussed work assignments, Ottawa, Ont., May 26-28, June 10-11, August 13, August 27, September 23-24, November 4, December 13, 1982; January 17-19, February 8, March 8, 1983.

Consulted with Combustion Engineering concerning materials and specimens for exposure in an experimental fluidized-bed-coal combustor, Windsor, Conn., December 15, 1982.

G. Hoey

Attended seventh CIM district 4 meeting, Saskatoon, Sask., October 8-10, 1982.

Attended NACE Eastern Can. reg. conf., Montreal, Que., November 22-25, 1982.

J.T. Jubb

Attended R&D Management course, Batelle, Columbus, Ohio, August 1-20, 1982.

Attended Research Board Meeting of WIC, Montreal, Que., October 13, 1982.

Inspected technical facilities at Babcock and Wilcox, Cambridge, Ont., April 19-20, 1982.

Attended WIC research board meeting, Toronto, Ont., January 18, 1983.

R.F. Knight

Met with DPW CN Marine, Halifax, N.S., August 11, 1982.

Examined fragments of a propane car, Montreal, Que., January 20, 1983.

Attended meeting of CSA committee on structural steel, Toronto, Ont., March 30, 1983.

M. Letts

Attended Gleeble 1500 Training Course, Duffers Ass., Troy, N.Y., May 26-28, 1982.

D. Lusk

Observed pipeline inspection procedures for certification program, Calgary, Alta., May 16-19, 1982.

D.K. Mak

Attended workshop on advanced NDE technology, Montreal, Que., May 30 and June 1, 1982.

Attended demonstration of KB 6000 at IMRI, NRC, Montreal, Que., May 13, 1982.

Visited Ontario Hydro Research labs and University of Toronto, Toronto, Ont., July 7-9, 1982.

Attended meeting of the Steering Committee for the International Conference on Pipeline Inspection, Edmonton, Alta., July 21-22, November 2-3, 1982; February 14, 1983.

Visited AECL Chalk River, Ont., August 10-11, 1982.

Visited Queen's University, Kingston, Ont., August 4; November 9-10, 1982.

T.F. Malis

Visited McGill University to discuss hot deformation of steel, Montreal, Que., April 6, 1982.

Obtained computer software and TEM/STEM data, Kingston, Ont., May 3-4, 1982.

Visited Bethlehem Steel and Lehigh University to discuss use of TEM/STEM and dilatometry, Allentown, Pa., June 1-3, 1982.

Visited University of Alberta for presentation and discussion related to PMRL projects, Edmonton, Alta., June 10-16, 1982.

Attended seminar on STEM at Ecole Polytechnique, Montreal, Que., July 19, 1982.

Visited M.I.T. to discuss analytical microscopy, Boston, Mass., August 13, 1982.

Attended seminar on deformation processing, St. Louis, Miss., October 22-24, 1982.

Trained on advanced aspects of TEM/STEM at Philips U.S., Mahwah, N.J., January 19-21, 1983.

Visited University of Waterloo on NSERC Major Installation Committee to evaluate a grant application concerning TEM/STEM, Waterloo, Ont., March 6-8, 1983.

Visited University of Western Ontario on NSERC Major Installation Committee to evaluate a grant application concerning surface analysis, London, Ontario, March 6-8, 1983.

J.T. McGrath

Attended progress meeting on a contract at the Welding Institute, Oakville, Ont., April 15-16, 1982.

Inspected technical facilities at Babcock and Wilcox, Cambridge, Ont., April 19-20, 1982.

Visited Stelco labs for discussion on Ti-N steels, Hamilton, Ont., May 1, 1982.

Attended a meeting of Canadian Council IIW, Montreal, Que., May 5, 1982.

Negotiated contract on weld process development project, Vancouver, B.C., May 11-15, 1982.

Visited Duffers Associates regarding Gleeble operation, Troy, N.Y., May 25-26, 1982.

Attended meeting at IMRI to discuss underwater welding facility, Montreal, Que., September 2, 1982.

Attended CSA meetings, Toronto, Ont., September 14-15, 1982.

Discussed cooperative program results at WIC, Toronto, Ont., November 29, 1982.

Attended a contract review meeting, Chinook Fuel Innovations Ltd., Calgary, Alta., January 11, 1983.

Attended a contract review meeting, WIC, Toronto, Ont., January 27, 1983.

K. Meleskie

Observed pipeline inspection procedures for the NDT certification program, Calgary, Alta., May 16-19, 1982.

Observed pipeline construction, Stittsville, Ont., August 17, 1982.

C.M. Mitchell

Visited Ontario Hydro to discuss development and marketing of CANMET Portable Stress Diffractometer, Toronto, Ont., June 16, 1982.

Discussed engineering model of the Portable X-ray Stress Diffractometer, Windsor, Ont., July 23, August 9, October 26, 1982 and March 15-16, 1983.

J.P. Monchalin

Discussed projects with supervisor at PMRL, Ottawa, Ont., April 14, June 16, October 22, 1982; March 16-23, 1983.

Visited pipeline inspection site and discussed NDT research, Calgary, Alta., June 1-3, 1982.

Attended meeting of Industrial Physics Division of Canadian Association of Physicists, Kingston, Ont., June 21, 1982.

Visited AECL, Chalk River, Ont., December 16, 1982.

Visited NDT section of Chalk River Laboratories, Chalk River, Ont., December 6-7, 1982.

Visited Electromec, Montreal, Que., February 14, 1983.

V.E. Moore

Attended CAMECA's CAMEBAX training course, San Diego, Calif., January 8, 1983.

J.R. Newbury

Attended demonstration of the KB 6000 at IMRI NRC, Montreal, Que., May 13, 1982.

Observed pipeline inspection procedures for the NDT Certification Program, Calgary, Alta., May 16-19, 1982.

Visited AECL, Chalk River, Ont., August 10-11, 1982.

Visited Queen's University to tests samples ultrasonically, Kingston, Ont., November 10, 1982.

J. Ng-Yellin

Attended seminar on STEM at Ecole Polytechnique, Montreal, Que., July 19, 1982.

Attended course to become more familiar with the EDAX equipment, Chicago, Ill., March 21, 1983.

R.F. Orr

Visited Canadian Liquid Air to observe narrow gap welding equipment, Montreal, Que., May 23, 1982.

R.H. Packwood

Lectured at symposium on surface science at University of Western Ontario, London, Ont., May 20-25, 1982.

Attended SCITEC Program Committee for November 1983 Conference, Montreal, Que., September 15, 1982.

Attended meeting of Advisory Board, Surface Science Lab UWO, London, Ont., December 9-10, 1982.

D.E. Parsons

Attended fracture-safe railway-car design course, CMHQ, Montreal, Que., April 1982.

Attended Steel Casting meeting., Mississauga, Ont., April 2, 1982.

Attended meeting at McMaster University re-free machining steel, Hamilton, Ont., June 1982.

Attended laboratory test certification, Galt, Ont., July 1982.

Attended rail research meeting, Ottawa, Ont., August 1982.

Attended CCGS ship safety meeting re Drill Rig Chain Link, Ottawa, Ont., March 1983.

Investigated accident, Edmonton and Calgary, Alta., March 29, 1983.

R.W. Revie

Attended meeting of the Canadian Council of ASM, April 5, 1982.

Discussed progress of joint funded work on H_2-induced linepipe cracking, Calgary, Edmonton, Alta., May 4-6, 1982.

Attended the dedication of the H.H. Eulig Corrosion Laboratory at M.I.T., Cambridge, Mass., May 13, 1982.

Attended meetings of the Steering Committee of the International Conference on Pipeline Inspection, Edmonton, Alta., May 6, July 21-22, November 2-3, 1982; February 14, 1983.

W.W. Roberts

Attended ASTM Committee E-24 Symposium on Fractography in Failure Analysis of Ceramics and Metals, Philadephia, Pa., April 28-30, 1982.

Visited McMaster University as a member of an NSERC committee to evaluate a grant application for a "Surface Chemical Analysis Microprobe (SAM, SIMS, XPS)", Hamilton, Ont., May 19-20, 1982.

Visited Laval University as a member of an NSERC committee to evaluate a grant application for a "Système d'analyse chimique des surfaces Auger-Esca-Sims", Quebec City, Que., May 24-25, 1982.

Visited McMaster University as a member of an NSERC site visit committee interviewing grant applicants, Hamilton, Ont., Dec. 15-17, 1982.

Visited University of Windsor as a member of an NSERC site visit committee interviewing grant applicants, Windsor, Ont., Dec. 15-17, 1982.

Visited University of Western Ontario as a member of an NSERC site visit committee interviewing grant applicants, London, Ont., Dec. 15-17, 1982.

Visited Queen's University as a member of an NSERC site visit committee, Kingston, Ont., January 11-13, 1983.

Visited University of Toronto as a member of an NSERC site visit committee, Toronto, Ont., January 11-13, 1983.

Visited University of Waterloo as a member of an NSERC site visit committee, Waterloo, Ont., January 11-13, 1983.

Attended meetings of the NSERC Chemical and Metallurgical Grant Selection Committee as Scientific Secretary, for the 1983-84 university grant competition, Conference Centre, Ottawa, Ont., February 13-18, 1983.

G.E. Ruddle

Visited Stelco R&D labs for discussion on Ti-N steels, Burlington, Ont., May 18, 1982.

Acted as scientific liaison on research agreement program with Professor Lenard of University of New Brunswick, Fredericton, N.B., July 2, 1982.

Attended CSIRA workshop on product quality control sensors as CANMET technical liaison officer, Toronto, Ont., March 8-9, 1983.

M. Sahoo

Attended foundry workshop at Queen's University, Kingston, Ont., May 2-4, 1982.

Acted as external examiner for an MSc student at Queen's University, Kingston, Ont., August 25, 1982.

Attended meeting of AFS, Chicago, Ill., October 5-6, 1982.

Made pressure test on six-valve-chest casting at Naval Engineering Test Establishment, Montreal, Que., January 2, January 27, 1983.

V.S. Sastri

Visited Alpha Resources to obtain information on H_2 analyser, Benton Harbor, Mich., May 20-21, 1982.

G. Smelsky

Observed installation of rolling-mill screwdown equipment, Peterborough, Ont., January 24, 1983.

E.I. Szabo

Visited Abex Corp., Joliette, Que., November 21-23, 1982.

R. Thomson

Visited Stelco to discuss clean steelmaking, Hamilton, Ont., June 9, 1982.

Negotiated a contract for offshore structures project, Waterloo, Ont., December 6, 1982.

Visited various oil company engineers, Calgary, Alta., January 25, 1983.

Discussed material supply in Canadian shipyards, Montreal, Que., February 14, 1983.

W.R. Tyson

Checked on the progress of a contract, Oakville, Ont., May 27, 1982.

Discussed steels for offshore structures with representatives of Canadian steel industry, Toronto, Ont., June 28, 1982.

Participated in CSA committee meetings, Toronto, Ont., September 15-16, 1982.

Attended meeting of advisory committee on ductile fracture at IMRI, Montreal, Que., December 2, 1982.

Visited DEW as liaison officer for IRAP grant, Montreal, Que., February 21, 1983.

Attended meetings of committees of CSA on properties of materials and pipeline steels, Vancouver, B.C., March 8-10, 1983.

Attended meeting of International Metals Reviews Committee, ASM, Cleveland, Ohio, March 14-15, 1983.

O. Vosikovsky

Presented seminar at Memorial University, St. Johns, Nfld., May 19-20, 1982.

Attended AGARD Meeting, Toronto, Ont., September 20-21, 1982.

Acquired information on data acquisition system, Waterloo, Ont., December 6, 1982.

R.D. Warda

Visited Holmes Foundry to demonstrate use of CANMET cupola software, Sarnia, Ont., May 16-19, October 18-19, 1982.

Attended meeting of AFS computer applications committee, Des Plaines, Ill., May 24-26, 1982.

Visited Cleveland CAE Metals Abrasives Limited, Welland, Ont., July 19-20, 1982.

Demonstrated cupola software at Kelsey Hayes, Woodstock, Ont., October 17-22, 1982.

Lectured at Penn. State University, Pa., October 25-29, 1982.

Delivered test equipment and presented work in Toronto, Ont., and Buffalo, N.Y., November 4-6, 1982.

Conferred with Hatch Associates, Toronto, Ont., February 7, 1983.

Visited various foundries in Ontario: Brantford, Woodstock, St. Catherines, February 20, 1983.

Participated in project work, St. Catherines, Guelph, Ont., March 20-24, 1983.

D.W.G. White

Visited Ecole Polytechnique to arrange for students to work at PMRL, Montreal, Que., May 11, 1982.

Visited Falconbridge Research Laboratories, Toronto, Ont., June 15, 1982.

Discussed engineering model of the portable X-ray stress diffractometer, PROTO Engineering, July 23, August 9, October 26, 1982; March 15-17, 1983.

Attended symposium on fundamental aspects of materials science in space, Ottawa, Ont., May 25-26, 1982.

Met with engineers of Davie Shipbuilding to discuss material problems with offshore structures, Quebec City, Que., May 20, 1982.

Discussed a possible contract on corrosion fatigue testing with University of Waterloo and WIC, Waterloo, Ont., June 21, 1982.

Discussed R&D with Algoma and Stelco, Toronto, Ont., June 28, 1982.

L.V. Whiting

Visited Holmes Foundry to demonstrate use of CANMET cupola software, Sarnia, Ont., May 16-19, October 17-22, 1982.

Discussed testing of CANMET cupola software with General Motors, St. Catherines, Ont., June 23, 1982.

Demonstrated cupola software at Kelsey Hayes, Woodstock, Ont., October 17-22, 1982.

Demonstrated cupola software at Massey Ferguson, Brantford, Ont., February 23, 1983.

Discussed quality control software at Dayton Walther, Guelph, Ont., March 21, 1983

Demonstrated cupola software at ITT, Aimco, St. Catherines, Ont., March 25, 1983.

PMRL GRANT AND MONITORING ACTIVITIES (1982-83)
DESIGNATED SCIENTIFIC AUTHORITIES AND LIAISON OFFICERS

SA/LO	Funding Org/Value (81-82)	Performer	Project
E.J. Biefer	(CANMET) $ 34,200	Caproco Corrosion Prevention Ltd.,	Underground corrosion of water pipes in Canadian cities
J.D. Boyd	(CANMET) $ 6,200	Chinook Fuel Innovations Ltd.,	Survey of requirements of plate steels in off-shore structures and arctic vessels

J.D. Boyd	(CANMET) $ 6,000	Price Waterhouse Assoc.	Market study to evaluate demand for direct quenched plate steel
D.C. Briggs	(CANMET) $ 57,300	Sherritt Gordon	Evaluation of stress-rupture properties of stainless alloys in FBC environments
R.J. Brigham	(CANMET) $178,000	GSW	Superchim 1495
R.K. Buhr	(CANMET) $ 19,700	Shnay Assoc.	Foundry sand survey
R.K. Buhr	(CANMET) $ 1,000	Dr. A. Mitchell Univ. of B.C.,	Personal service contract electroslag casting
V.L. Caron	(CANMET) $ 80,000	Tektrend Int.,	Development of on-line acoustic emission monitoring for welding thick-walled vessels
R. Chandel	CANMET $ 40,000	WIC	Study of weld cracking in 2¼ Cr - 1Mo steel
A.F. Crawley	CANMET $ 27,800	McMaster Univ.	Microstructural features limiting formability in mass-produced cold forgings
A.F. Crawley	CANMET $ 21,200	McMaster Univ.	Microchemistry and transformation kinetics of experimental batch-annealed dual-phase steels

A.F. Crawley	PRAI (NRC) $ 72,600	McMaster Univ./ Dofasco	P. 8216
A.F. Crawley	RAP $ 8,000	McMaster Univ.	An investigation of the intercritical annealing of dual-phase steels
K.G. Davis	CANMET $ 23,500	Prof. M. Salcudean Univ. of Ottawa	Mathematical modelling of heat flow in permanent moulds
D.M. Fegredo	CANMET $ 12,400	Dr. E.E. Laufer Technical Univ. of Nova Scotia	TEM study of effects of simulated rail loading on an experimental premium rail steel
D.M. Fegredo	RAP $ 8,000	Dr. E.E. Laufer Tech. Univ. of Nova Scotia	Wear mechanisms in premium rail
B. Faucher	CANMET $ 8,800	High Vacuum	Design and construction of an environmental chamber
J.B. Gilmour	CANMET $ 6,400	Prof. D. Burns Univ. of Waterloo	Design of experiments to evaluate the fatigue and corrosion fatigue properties of welded structures
M.J. Godden	CANMET $ 64,000	Prof. D.L. Atherton Queen's Univ.	Investigation of the effects of mechanical stress on the magnetic properties of pipeline steels for pipeline stress monitoring

G.R. Heny	CANMET $ 22,800	Research and Productivity Council	Development of an erosivity test for the characterization of coal water fuels
A.W. Loi	CANMET $ 51,400	Montreal Engineering	Design, construction and testing of a high temperature erosion test facility
D.K. Mak	CANMET $ 60,000	Techno-Scientific	Automated ultrasonic test system for characterization of defects in weldments
T.F. Malis	CANMET $ 45,000	Prof. J.D. Embury McMaster Univ.	Scanning transmission electron microscopy studies of HSLA steels
J.T. McGrath	CANMET $ 41,600	Prof. B.M. Patchett Univ. of Alberta	Welding of heavy-section pressure vessel steels by narrow-gap process
J.T. McGrath	CANMET $ 25,000	Dr. A. Mitchell Univ. of British Columbia	Fabrication of pressure vessel nozzles
J.T. McGrath	CANMET $287,000	Chinook/VMD	Weld process development for fabrication of heavy-wall pressure vessels
J.T. McGrath	CANMET $225,000	Babcock and Wilcox	Weld process development for fabrication of heavy-wall pressure vessels
D.E. Parsons	CANMET $ 31,500	Prof. D.A.R. Kay McMaster Univ.	Development of non-leaded free-machining steels

G. Roy	CANMET $ 26,000	Prof. R. Pick Univ. of Waterloo	Finite element modelling of multipass welds
G. Roy	CEA $ 40,000	Ontario Hydro	Qualification studies on sectioning techniques for residual stress measurements
G. Roy	RAP $ 10,000	Prof. J.A. Goldak Carleton Univ.	Elasto-plastic finite element analysis
G.E. Ruddle	CANMET $ 47,500	Prof. J.J. Jonas McGill Univ.	Prevention of duplex grain structures in control-rolled HSLA steel plate
G.E. Ruddle	CANMET $ 53,600	Prof. J.J. Jonas McGill Univ.	Effects of Mo, Ti, Nb on the hot working (controlled-rolling) of linepipe steels
G.E. Ruddle	CANMET $ 19,700	E. Leaver Consultant	Quality control sensors to improve energy conservation in steel mills
M. Sahoo	CANMET $ 36,000	Ecole Polytechnique	Corrosion-fatigue of Mn-Ni-Al bronze propeller alloys
M. Sahoo	CANMET $ 18,500	WIC	Welding fume characteristics of Cu-Ni alloy GMA electrodes
R. Thomson	CANMET $105,000	Stelco	Determination of the ability of Stelco ingot and strand-cast structural plate to meet the mechanical property requirements for Canadian offshore structures and Arctic ships

R. Thomson	CANMET $ 53,000	AMCA	A study to examine the suitability of two candidate steels which can be produced in Canada for use in the construction of offshore structures and arctic vessels
R. Thomson	CANMET $ 3,500	Prof. D. Burns Univ. of Waterloo	Survey of welded joint specifications for Eastern and Arctic orfshore structures
W.R. Tyson	CANMET $ 65,000	Saskatchewan Research Council	Design of heavy-section fracture testing machine
W.R. Tyson	CANMET $ 17,900	Ontario Research Foundation	Fracture resistance characterization of Canadian steels
W.R. Tyson	CANMET $ 43,000	Prof. D.S. Wilkinson, McMaster Univ.	Materials and design for resistance to crack growth by creep
W.R. Tyson	RAP $ 7,000	Prof. W.E. White, Univ. of Calgary	Elevated temperature creep studies on materials for energy systems
W.R. Tyson	RAP $ 11,000	Prof. D.M.R. Taplin, Univ. of Waterloo	The role of stress-state and environment on creep fracture in super alloys
W.R. Tyson	RAP $ 7,000	Prof. D.S. Wilkinson, McMaster Univ.	The role of impurities on creep fracture in low alloy steels
W.R. Tyson	IRAP $ 81,600	Dominion Eng. Works	GMR 1139
W.R. Tyson	IRAP $ 42,000	AMCA Int.	Local 1154

O. Vosikovsky	CANMET $ 10,000	Prof. R. Bell, Carleton Univ.	Deformation of stress intensity factors for weld defects
O. Vosikovsky	CANMET $ 28,000	Prof. D.W. Reddy, Memorial Univ.	Corrosion fatigue of tubular joints for off-shore structures
O. Vosikovsky	CANMET $ 15,000	Prof. D.W. Hoeppner, Univ. of Toronto	Corrosion fatigue of structural materials
O. Vosikovsky	CEA $230,000	Ontario Hydro	Corrosion fatique cracking in fossil fired boilers
R.D. Warda	CANMET $ 28,800	Hatch & Associates	Influence of tuyère velocity on cupola melting performance
R.D. Warda	CANMET $ 20,000	Queen's Univ.	Development of computer assisted risering program
D.W.G. White	CANMET $ 59,000	EG & G Canada	Development of position sensitive detectors for a prototype portable stress diffractometer
D.W.G. White	CANMET $ 45,000 $ 37,500	Proto Manufacturing	Design and construction of a prototype portable stress diffractometer
D.W.G. White	CANMET $ 10,000	P. Kirby	Prepare specifications and file application for patent on the CANMET portable X-ray stress diffractometer

D.W.G. White	CANMET $ 6,100	Chollet - Private Consultant	Assessment of long term R&D in Canada's non-ferrous metals manufacturing industry
L.V. Whiting	CANMET $ 11,500	ORF	Protective coatings for components of fossil energy conversion systems
L.V. Whiting	CANMET $ 30,000	ORF	Chemical vapour-deposited coatings for high temperature corrosion resistance

PMRL PROJECT LEADERS

Corrosion Mechanisms	360001	J.B. Gilmour
Corrosion of Municipal Water Piping	360002	G.J. Biefer
Plastic Flow, Fracture and Stress Analysis	360041	W.R. Tyson
X-Ray Stress Diffractometer	360042	D.W.G. White
Microstructural Effects on Strength and Toughness in Engineering Alloys	360051	J.D. Boyd
Development of Non-Leaded Free Machining Steels	360052	D.E. Parsons
Zinc-Base Foundry Alloys	360055	M. Sahoo
Development of Instrumentation and Techniques	360081	R.N. Packwood
Cost Recovery in Mineral Technology Development	360091	W.H. Erickson
Transfer of Materials Development Technology to Industry	360092	R.F. Knight
Exploratory Foundry Research	370001	R.K. Buhr

Technology for the Metal Casting Industry	370002	R.K. Buhr
Degradable Sand and Core Binders	370003	R.K. Buhr
Electroslag Casting	370006	R.K. Buhr
Gravity Permanent Mould Casting	370015	R.K. Buhr
Low Pressure Disposable Mould Casting	370016	R.K. Buhr
Improved Cupola Melting Practice	370017	R.K. Buhr
Rolling Mill Processing Technology	370032	A.F. Crawley
Formability and Processing of Sheet Steels	370034	A.F. Crawley
Fluidized Bed Metal Processing	370035	A.F. Crawley
Near Net Shape Forging	370036	A.F. Crawley
Weld Mechanics	370052	J.T. McGrath
Thermal/Mechanical Simulation of Metallurgical Processes	370053	J.T. McGrath
Effect of Nitrogen on Weld Notch Toughness	370054	J.T. McGrath
Heat Treated Rail	370071	D.M. Fegredo
Marine Materials	370072	R. Thomson
Naval Materials	370073	M. Sahoo
Cost Recovery in Metals Processing Technology	370091	W.H. Erickson
Transfer of Metals Processing Technology to Industry	370092	J.T. Jubb
Certification of NDT Personnel	380021	V.L. Caron
Materials for Tar Sands Processing	420501	A.W. Lui
Pressure Vessels	420502	J.T. McGrath
Welding Process Development	420503	J.T. McGrath

Development and Evaluation of High Strength Steels for Oil and Gas Pipelines	420601	M.J. Godden
Degradation, Inspection and Repair of Pipelines	420602	M.J. Godden
Fabrication of Pipelines	420603	M.J. Godden
Materials for Offshore Structures	420604	R. Thomson
Cost Shared Industrial Program on Steels for Offshore Structures	420605	R. Thomson
Structural Integrity Monitoring of Offshore Structures	420606	R. Thomson
Materials for Coal Handling and Utilization	430901	A.M. Lui
Materials for High-Temperature Energy and Conversion Processes	430902	A.M. Lui

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

INTERNATIONAL CONFERENCE ON PIPELINE INSPECTION

Steering Committee

(chairman) R.M. Ravie
(member) B.K. Mak

INTERNATIONAL CONFERENCE ON PROPERTIES, FABRICATION DESIGN AND APPLICATIONS FOR HSLA STEELS

1983 organizing committee (member) J.B. Boyd

9th INTERNATIONAL CONGRESS ON METALLIC CORROSION

Technical program committee

(member) R.M. Ravie

INTERNATIONAL INSTITUTE OF WELDING

Canadian Council

	(chairman)	J.T. McGrath
	(exec. secy)	R.B. McDonald
	(member)	J.T. Jobb

Commission X, Residual Stress, Stress Relieving Brittle Fracture

(chairman)	J.T. McGrath

Commission XIII, Fatigue Testing Committee

(member)	B. Vasilovsky

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Canadian Advisory Committee

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SC7,	Test Methods other than Mechanical and Chemical Analysis	(member)	R.E. Parsons
SC11,	Steel Castings	(member)	V.L. Caron
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TC25,	Cast Iron	(member)	R.E. Bahr
TC135/SC7	NDT Personal Qualification International Secretariat	(secy)	V.L Caron
TC155,	Nickel and Nickel Alloys	(member)	R.J. Lavigne

TC156/WG1	Corrosion of Metals and Alloys/Terminology		
		(member)	G.J. Siefer
TC164,	Mechanical Testing of Metals		
		(member)	A.F. Crawley
		(member)	B. Vasilovsky

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Interdepartmental Committee, Committee for Scientific and Technological Policy

(dept. rep.) V.L. Caron

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(member) A.F. Crawley

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(secy) M. Sahoo

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		(member)	O. Vosikovsky
E-24.04.05	Task Group on Fatigue Crack Growth Rate Testing in Aqueous Environments		
		(member)	O. Vosikovsky

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Task Group T-IF-1,	Sulphide Stress Cracking Resistant Metallic Materials for Oil Field Equipment		
		(member)	G.J. Biefer
Task Group T-IF-9, TM-01-77,	Standard to Evaluate Metallic Materials for sour Service		
		(member)	G.J. Biefer
Task Group T-IF-20,	Stepwise Cracking of Pipeline Steels		
		(member)	G.J. Biefer
Unit Committee T-IF,	Metallurgy of Oil Field Equip ment	-	
		(member)	G.J. Biefer
Group Committee T-1,	Corrosion Control in Petroleum Production		
		(member)	G.J. Biefer

WELDING RESEARCH COUNCIL

High Alloys Committee — (member) — M.J.A. Lavigne

Sub-Committee on Corrosion Resistance — (member) — M.J.A. Lavigne

Sub-Committee on Heat Resistant Alloys — (member) — M.J.A. Lavigne

CANADIAN - FEDERAL

CANADIAN ARMED FORCES CORROSION PREVENTION COMMITTEE

Ottawa Sub-Committee — (member) — J.B. Gilmour

CANADIAN ELECTRICAL ASSOCIATION

Hardfacing in Coal-Fired Power Stations — (member) — K.G. Davis

CANADIAN GOVERNMENT SPECIFICATIONS BOARD

48-GP Nondestructive Testing — (member) — V.L. Caron

52-GP Specifications for Major Kitchen Equipment — (member) — R.D. McDonald

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CANMET

Committee on Environment Improvement — (member) — R.K. Buhr

Committee on Electronic Data Processing — (member) — D.W.G. White

(member) — K.S. Milliken

Committee on Official Languages in Publications — (PMRL rep.) — D.W.G. White

NSERC		
Major Installations Committee	(member)	T.F. Malis
Chemical and Metallurgical Grants Selection Committee	(scientific secy)	M.H. Roberts
TRANSPORT CANADA		
Ship Plate Committee	(member)	B.E. Parsons
Propeller Castings Committee	(member)	B.E. Parsons
Interdepartmental Automobile R&D Panel Technical Sub-Committee	(member)	A.F. Crawley
Interdepartmental Group on R&D in Pipelines	(CANMET rep.)	M.J. Goddon

CANADIAN - MISCELLANEOUS

ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN CANADA	(hon. secy)	R.N. Pachmood
CANADIAN ASSOCIATION OF PHYSICISTS DIVISION OF INDUSTRIAL AND APPLIED PHYSICS	(chairman)	J.P. Monchalin
CANADIAN COMMITTEE FOR RESEARCH ON THE STRENGTH AND FRACTURE OF MATERIALS	(board member)	W.R. Tyson
CANADIAN FRACTURE CONFERENCE ON MODELLING PROBLEMS IN CRACK TIP MECHANICS	(member advisory committee)	W.R. Tyson
CANADIAN GAS ASSOCIATION Corrosion Control Committee	(member)	E.J. Biefer

CANADIAN INSTITUTE OF MINING AND METALLURGY

Editorial Board	(member)	J.D. Boyd
Materials Engineering Committee	(member)	M.R. Tyson
	(secy-treas.)	A.F. Crawley
Metallurgical Society, Corrosion Section	(past-chairman)	G.R. Hoey
Metallurgical Society, Publications Committee	(chairman)	J.D. Boyd
	(member)	J.B. Gilmour
Ottawa Branch	(past-chairman)	W.H. Erickson
	(exec. member)	J.D. Boyd

CANADIAN METALLURGICAL QUARTERLY

	(assist. editor)	J.D. Boyd

33rd CANADIAN METAL PHYSICS CONFERENCE

Organizing Committee	(chairman)	J.D. Boyd
	(member)	G. Carpenter

CANADIAN STANDARDS ASSOCIATION

Cast Iron	(member)	R.K. Buhr
Fracture Toughness Task Group	(member)	J.T. McGrath
Lead and Lead Alloys	(member)	A. Couture
Nickel and Nickel Alloys	(member)	M.J. Lavigne
Pipeline Material	(member)	M.R. Tyson
Properties of Materials	(member)	M.R. Tyson
Steel Castings	(member)	D.E. Parsons
Steel Line Pipe for Research	(member)	M.R. Tyson

Structural Steel		
	(member)	R.F. Knight
Welding Sub-Committee		
	(member)	J.T. McGrath
CANADIAN SOCIETY FOR NONDESTRUCTIVE TESTING FOUNDATION		
Executive Member and Board Trustee		
	(member)	V.L. Caron
Long Term Planning Committee		
	(member)	V.L. Caron
Board Trustee		
	(member)	M.M. Ericksen
COMMITTEE ON COPPER CASTINGS FOR THE CANADIAN STEEL INDUSTRY COMMITTEE		
	(chairman)	R.K. Buhr
Commission to implement a new course in physical technology between CEGEP and industry		
	(member)	J.P. Monchalin
THE ELECTROCHEMICAL SOCIETY INC.		
Ontario-Quebec Section		
	(treas.)	R.W. Revie
INDUSTRIAL CONSULTING COMMITTEE FOR MONITORING THE RESEARCH ACTIVITIES ON ZINC-BASE FOUNDRY ALLOYS		
	(founder)	M. Sahoo
	(member)	M. Sahoo
INDUSTRIAL LIAISON COMMITTEE, UNIVERSITY OF ALBERTA WELDING ENGINEERING PROGRAM		
	(member)	J.T. McGrath
JOINT STEEL COMPANY PROJECT		
Technical Advisory Committee on Sheet Steels		
	(member)	A.F. Crawley
OTTAWA VALLEY ELECTRON BEAM GROUP		
	(co-chairman)	R.M. Packwood

SPECTOGRAPHY SOCIETY OF CANADA

Task Committee for Reference Materials Project

(member) R.D. McDonald

UNIVERSITY OF WESTERN ONTARIO

Surface Science Laboratory, Board of Directors

(member) R.H. Packwood

WELDING INSTITUTE OF CANADA

Research Board

(member) J.T. Jubb

WELDING UPDATE 1983

Organizing committee

(member) J.T. McGrath

(member) J.E.M. Braid

PART E. TECHNOLOGY EXCHANGE

Partial List of companies, government agencies, universities, and research organizations with which PMRL has been associated during FY 1982-83.

INDUSTRY

A

Abex Corp.	Joliette, Que.
Abex Corp.	Mahwah, N.J.
Alberta Energy Co. Ltd.	Edmonton, Alta.
Alberta Rockwool Corp.	Calgary, Alta.
Alcan Canada Ltd.	Kingston, Ont.
Algoma Steel	Sault Ste. Marie, Ont.
Alloy Foundry	Merrickville, Ont.
Alpha Cast Inc.	Whitewater, Wis.
Alpha Resources	Boston Harbor, Mich.
AMCA International	Montreal, Que.
AMCA International	Ottawa, Ont.
Arctec Canada Ltd.	Kanata, Ont.
Ardiem Inc. Corp.	Vancouver, B.C.
Associated Foundry	Surrey, B.C.
Atlas Steel	Welland, Ont.
Aurora Metals Division	Montgomery, Ill.

B

Babcock & Wilcox	Cambridge, Ont.
Badone, L. Assoc. Ltd.	Willowdale, Ont.
Beaumart Ltée.	Contrecoeur, Que.
Belgen Foundry	Drummondville, Que.
Bell Northern Research	Ottawa, Ont.
Bethlehem Steel Corp.	Pittsburgh, Pa.
Bethlehem Steel Corp.	Bethlehem, Pa.
Blaw - Knox	Chicago, Ill.
Bow Valley, Offshore Drilling Ltd.	Calgary, Alta.
British Steel Corp.	Middlesborough, U.K.
Brom Foundry & Machine Co., Ltd.	Winona, Minn.
Brown Boggs Ltd.	Hamilton, Ont.
Burnstein Castings Ltd.	St. Catherines, Ont.

C

CAE Welmet Industries Ltd.	Welland, Ont.
Canadian General Electric	Peterborough, Ont.
Canadian Industries Ltd.	Montreal, Que.
Canadian Insulation Service	Montreal, Que.
Canadian Liquid Air Ltd.	Montreal, Que.
Canadian Marine Drilling	Calgary, Alta.
Canadian Pacific Railways	Montreal, Que.
Canadian Stone Marine Ltd.	Iberville, Que.
Canertech Inc.	Winnipeg, Man.
Canron Foundry	Hamilton, Ont.
Caproco Ltd.	Edmonton, Alta.
Carborundum Corp.	Bethlehem, Pa.
Central Wire	Perth, Ont.
Chinook Fuel Innovations Ltd.	Calgary, Alta.
Cleveland CAE Metal Abrasives Ind.	Welland, Ont.
Climax Molybdenum Co.	Golden, Colo.
Combustion Engineering - Superheater Ltd.	Ottawa, Ont.

Corrosion Service Co.	Toronto, Ont.
Creusot-Loire	France

D

Darling Bros. Ltd.	Montreal, Que.
Davie Shipbuilding	Lauzon, Que.
Davis Engineering	Ottawa, Ont.
Dayton Malleable Iron Co.	Dayton, Ohio
Dayton-Walther Foundry	Guelph, Ont.
Dofasco	Hamilton, Ont.
Det Norske Veritas	Calgary, Alta.
Dome Petroleum Ltd.	Calgary, Alta.
Dominion Bridge	Ottawa, Ont.
Dominion Bridge	Edmonton, Alta.
Dominion Bridge	Hawksbury, Ont.
Dominion Engineering Works	Montreal, Que.
Duffers Associates	Troy, N.Y.
Dynawest Projects Ltd.	Calgary, Alta.

E

E.B. Eddy Forest Products Ltd.	Ottawa, Ont.
Eirich Canada	Maple, Ont.
Electromec	Quebec City, Que.
Engineering Products of Canada Ltd.	Boucherville, Que.
Engineers India Ltd.	New Delhi, India
Enterprise Foundry	Sackville, N.B.
ESAB AB	Sweden, Norway
ESAB AB	Montreal, Que.
Esco Corp.	Portland, Oreg.
Esco Corp.	Port Coquitlam, B.C.
Esso Resources Ltd.	Calgary, Alta.

F

Falconbridge Nickel Mines Ltd.	Toronto, Ont.
Ferrco	Whitby, Ont.
Fleetwood Metal Ind.	Tilbury, Ont.
Fonderie Antique	Athabasca, Que.
Foote Mineral Corp.	Chicago, Ill.
Forintek Canada Corp.	Ottawa, Ont.

G

General Casting Corp.	Milwaukee, Wis.
General Motors	St. Catherines, Ont.
Global Canatom	Cambridge, Ont.
Goodkey Weedmark & Associates	Ottawa, Ont.
Gulf Canada Ltd.	Calgary, Alta.
Gulf Canada Resources Co., Ltd.	Calgary, Alta.

H

Habitation Nordique	Quebec City, Que.
Hanson Material Engineering	Edmonton, Ont.
Hamilton Foundry	Hamilton, Ont.
Hatch Associates	Toronto, Ont.
Hayes Stuart Inc.	Montreal, Que.
High Vacuum Systems Inc.	Brampton, Ont.
Holmes Foundry	Sarnia, Ont.
Hooper & Angus Ltd.	Toronto, Ont.
Husky Oil	Lloydminster, B.C.

I

IMP Foundry Ltd.	Dartmouth, N.S.
Imperial Oil Ltd.	Toronto, Ont.
Industries Union Screen Plate Inc.	Lennoxville, Que.
Industries Valcartier	Courcelette, Que.
Inproheat Ltd.	Vancouver, B.C.
International Harvester	Hamilton, Ont.
International Harvester	Chicago, Ill.
International Paint Co.	Montreal, Que.
Interprovincial Steel & Pipe Corp., Ltd.	Regina, Sask.
ITT Aimco Ltd.	St. Catherines, Ont.

K

Kelsey Hayes Ltd.	Woodstock, Ont.
Kidd Creek Mines Ltd.	Edison, N.J.
Krupp-Quakertown	Cambridge, Ont.
Kulp Foundry	Stroudsburg, Pa.
Kwicki	Calgary, Alta.

L

Lake Ontario Steel Corp.	Whitby, Ont.
Leaver, E.W.	Willowdale, Ont.
Lincoln Electric	Toronto, Ont.
Lloyds Registry	Montreal, Que.

M

Magdalen Silica	Montreal, Que.
Massey Ferguson	Brantford, Ont.
McLean Foundry	Brantford, Ont.
Metallurgical Consultants, Inc.	Houston, Tex.
Minexpert Inc.	Montreal, Que.
Modern Castings	Des Plaines, Ill.
Mondel Eng.	Mississauga, Ont.
Montreal Engineering Co.	Toronto, Ont.
Mueller Industries	St. Jérome, Que.

N

NOVA - An Alberta Corp.	Calgary, Alta.
Nippon Steel	Kimitsu, Japan
Noranda Mines, Ltd.	Murdockville, Que.
Noranda Research Centre	Pointe Claire, Que.
Nordco	St. John's, Nfld.

O

ODC/OILFAB	St. Johns, Nfld.
Optotek	Ottawa, Ont.
Orangeville Foundry	Orangeville, Ont.

P

Pacific Enercon	Grandforks, B.C.
Partec - Lavalin	Toronto, Ont.
Pfizer	Montreal, Que.
Pfizer International	New York, N.Y.
Plant Adjustment Bureau Ltd.	Moncton, N.B.
Price Waterhouse Assoc.	Toronto, Ont.

Q

Quatar General Petroleum	Quatar
Quatic Chemicals	Cambridge, Ont.
Quebec Iron & Titanium	Sorel, Que.

R

Republic Steel Corp.	Buffalo, N.Y.
Roxul Corp.	Milton, Ont.

S

Servimet Inc.	Tracy, Que.
Shnay Roberts & Assoc.	Montreal, Que.
Shell Canada Resources	Calgary, Alta.
Sherritt Gordon Mines Ltd.	Fort. Sask., Alta.
Sidbec-Dosco	Contrecoeur, Que.
Sonco Steel Tubing	Brampton, Ont.
Spar Aerospace	Toronto, Ont.
St. John Shipbuilding	St. John, N.B.
Standard Induction Casting	Windsor, Ont.
Stainless Foundry & Engineering Corp.	Milwaukee, Wis.
Stanton Foundry	St. Hubert, Que.
Stanton Pipes Ltd.	Hamilton, Ont.
STELCO	Hamilton, Ont.
Steelflow Inc.	Okotoks, Alta.
Stittsville Foundry	Stittsville, Ont.
SUNCOR	Sarnia, Ont.
Sysco	N. Sydney, N.S.

T

Techno Scientific Inc.	Downsview, Ont.
Tektrend Int'l Ltd.	Lachute, Que.
Tonawanda Coke Corp.	Tonawanda, N.Y.
TransCanada Pipelines	Toronto, Ont.
Transportation Development Centre	Montreal, Que.

U

Union Carbide	Montreal, Que.
Union Carbide	Toronto, Ont.
Union Gas	Chatham, Ont.
United States Steel Corp.	Monroeville, Pa.

V

Vada Industries Ltd.	Okotoks, Alta.
Vickers Ruwolf Adams Foundry	Victoria, Aus.
Victoria Machining Depot	Victoria, B.C.

W

Westinghouse R&D Centre	Pittsburgh, Pa.
Wotherspoon Foundry	Oakville, Ont.

Y

York Barbell Co. Ltd.	Oakville, Ont.

Z

Zalev Bros.	Windsor, Ont.

GOVERNMENT DEPARTMENTS AND AGENCIES

A

Agriculture Canada	Ottawa, Ont.
Atomic Energy of Canada	Chalk River, Ont.
Atomic Energy Control Board	Ottawa, Ont.

C

Canada Customs	Ottawa, Ont.
Canadian Coast Guard	Ottawa, Ont.
Canadian National Railways	Montreal, Que.
Canadian Pacific Railways	Montreal, Que.
Canadian Patents and Development Ltd.	Ottawa, Ont.
Canadian Transport Commission, Dept. of	Ottawa, Ont.

D

Defense Research Est. Atlantic	Halifax, N.S.
Defense Research Est. Pacific	Esquimalt, B.C.

E

Eldorado Nuclear	Ottawa, Ont.
Export Development Corp.	Ottawa, Ont.

H

Health & Welfare Canada	Ottawa, Ont.

I

Industry, Trade & Commerce, Dept. of	Ottawa, Ont.

N

National Defence, Dept. of	Ottawa, Ont.
National Defence, Dept. of	Halifax, N.S.
National Energy Board	Ottawa, Ont.
National Museums of Can.	Ottawa, Ont.
National Research Council IMRI	Montreal, Que.
National Research Council	Ottawa, Ont.
National Research Council-Tribology Laboratory	Vancouver, B.C.

P

Petro Canada	Calgary, Alta.

Public Works Canada	Ottawa, Ont.
R	
Royal Canadian Mint	Ottawa, Ont.
S	
Science & Technology - Ministry of State for	Ottawa, Ont.
Supply & Services, Dept. of	Ottawa, Ont.
T	
Transport Canada	Ottawa, Ont.
W	
Whiteshell Nuclear Research Est.	Pinawa, Man.

UNIVERSITIES & OTHER ORGANIZATIONS

A	
Alberta, University of	Edmonton, Alta.
Alberta Research Council	Calgary, Alta.
American Foundrymen's Society	Buffalo, N.Y.
American Foundrymen's Society	Des Plaines, Ill.
American Foundrymen's Society	Quebec, Que.
American Hot Dip Galvanizing Assoc.	New York, N.Y.
American Society for Metals	Metals Park, Ohio
American Society for Metals	St. Louis, Miss.
B	
B.C. Hydro	Vancouver, B.C.
British Columbia, University of	Vancouver, B.C.
C	
Cambridge, University of	Cambridge, U.K.
Canadian Continuous Steel Casting Res. Assoc.	Welland, Ont.
Canadian Electrical Assoc.	Montreal, Que.
Canadian Standards Assoc.	Toronto, Ont.
Canadian Welding Bureau	Toronto, Ont.
Carleton University	Ottawa, Ont.
Concordia University	Montreal, Que.
CSIRA	Burlington, Ont.
D	
Dar Es Salaam, University of	Dar es Salaam, Tanzania
E	
Ecole Polytechnique	Montreal, Que.
G	
Grey Iron Research Institute	Columbus, Ohio
Georgia Tech., Institute of Technology	Atlanta, Ga.
J	
Japan Society for Tech. of Plasticity	Tokyo, Japan

L

Laval University	Quebec City, Que.

M

McGill University	Montreal, Que.
McMaster University	Hamilton, Ont.
Mohawk College	Hamilton, Ont.

N

National Association of Corrosion Engineers	Houston, Texas
National Engineering Lab.	East Kilbride, Scotland
New Brunswick, University of	Fredericton, N.B.
Nova Scotia Power Corp.	Halifax, N.S.

O

Ontario Hydro	Toronto, Ont.
Ontario Research Foundation	Mississauga, Ont.
Ottawa, University of	Ottawa, Ont.

P

Peking Institute of Metallurgy	Peking, China
Penn State University	State College, Pa.

Q

Queen's University	Kingston, Ont.
Quebec Hydro	Quebec, Que.

R

Research & Productivity Council of New Brunswick	Fredericton, N.B.
Royal Military College	Kingston, Ont.

S

Saskatchewan Research Council	Saskatoon, Sask.
Stuttgart, University of	Stuttgart, W. Germany

T

Technical Research Centre	Finland
Technical University of Nova Scotia	Halifax, N.S.
Toronto, University of	Toronto, Ont.

U

U.S. Bureau of Mines	Minneapolis, Minn.

W

Waterloo, University of	Waterloo, Ont.
Western Ontario, University of	London, Ont.
Windsor, University of	Windsor, Ont.
Welding Institute (The)	Abington, U.K.
Welding Institute of Canada	Oakville, Ont.

PART F. PROFESSIONAL STAFF

M.H. Erickson	B.Sc., M.Sc. (Mich. Tech.), Ph.D. (Durham), P.Eng.	Director
M.H. Roberts	M.A., Ph.D. (Leeds)	Program and Planning Coordinator

METAL PROCESSING LABORATORY

J.T. Jobb	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Manager

Foundry Section

R.K. Bahr	B.Eng. (McGill)	Section Head
K.G. Davis	B.Sc. (Birmingham), M.A.Sc. Ph.D. (U.B.C.)	Res. Sci.
J.L. Dion	B.A.Sc. (Montreal)	Phys. Sci.
R.A. Hatte	B.Eng. (Sherbrooke U.)	Eng.
G. Morin	B.A.Sc. (Laval), P.Eng.	Eng.
A. Palmer	B.Sc., Ph.D. (London), P.Eng.	Eng.
E.I. Szabo	M.Sc., Ph.D. (Nottingham)	Res. Sci.
R. Thomson	B.Sc., ARCST, Ph.D. (Glasgow)	Res. Sci.
R.D. Warda	B.A.Sc. (U.B.C.), Ph.D. (Cambridge)	Res. Sci.
L.V. Whiting	B.Sc., M.Sc., Ph.D. (McGill) M.B.A. Ottawa U.	Res. Sci.

Metal Forming Section

A.F. Crawley	B.Sc., Ph.D. (Glasgow) P.Eng.	Section Head
D.L. Baragar	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
J.A. Mainville	B.Sc. (Montreal)	Phys. Sci.
W.A. Pollard	B.Sc. ARSM (London), P.Eng.	Res. Sci.
G.E. Ruddle	B.A.Sc., M.Sc. (Waterloo) D.Sc. (Virginia) P.Eng.	Res. Sci.
J.J.M. Too	B.Sc. (Taiwan), M.Sc. (McGill), Ph.D. (Wales)	Res. Sci.

Nondestructive Testing Section

V.L. Caron	B.A.Sc. (Laval), M.Eng. (Paris) P.Eng.	Section Head
G. Landry	B.A.Sc. (Montreal)	Phys. Sci.
D.K. Mak	B.Sc., M.Sc., Ph.D. (Toronto)	Res. Sci.
J.P. Monchalin	D.Eng (Paris), M.Sc., Ph.D. (Wales)	Res. Sci.

Welding Section

J.T. McGrath	B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.	Section Head
J.T. Bouker	B.Met., Ph.D., (Sheffield)	Res. Sci.
J.E.M. Braid	B.A.Sc. (Waterloo), Ph.D. (Cambridge)	Res. Sci.
R.S. Chandel	B.E. (Nagpur), Ph.D. (Birmingham), C.Eng. M.I.M.	Res. Sci.
R.D. McDonald	B.Sc. (Queen's), P.Eng.	Res. Sci.

METAL DEVELOPMENT LABORATORY

B.M.G. White	S.M., Sc.D. (M.I.T.), P.Eng.	Manager

Corrosion Science Section

J.B. Gilmour	B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.	Section Head
G.J. Biefer	B.Sc., Ph.D. (McGill)	Res. Sci.
D.C. Briggs	B.Eng., M.Eng. (McGill), Ph.D. (Queen's)	Res. Sci.
R.J. Brigham*	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
H.M. Hindan	B.Sc. (Cairo), Ph.D. (McMaster)	Res. Sci.
G.R. Hoey	B.Sc., M.Sc., Ph.D. (Toronto)	Res. Sci.
A.W. Lui	B.Sc., M.A.Sc. (Queen's), Ph.D. (Windsor)	Res. Sci.
R.W. Revie**	B.Eng. (McGill), M.Eng. (R.P.I.) Ph.D. (M.I.T.)	Res. Sci.
J.C. Saddington	Chem. Eng., M.A.Sc. (Toronto)	Res. Sci.
V.S. Sastri	B.Sc., M.A., Ph.D. (State U of N.Y.)	Res. Sci.

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* Seconded to ADM's Office

** Seconded to Program Office

Engineering and Metal Physics Section

M.R. Tyson	**B.A.Sc. (Toronto), Ph.D. (Cambridge)**	**Section Head**
M. Boutin	B.Eng., M.A.Sc. (Montreal)	Phys. Sci.
G. Carpenter	B.Sc., Ph.D. (Wales)	Res. Sci.
E.J. Cousineau	B.Sc. (Carleton)	Phys. Sci.
B. Faucher	Eng. INSA (Lyon), M.Sc. (Laval), Ph.D. (Ottawa), P.Eng.	Res. Sci.
J. Harbec	B.Eng. (McGill), P.Eng.	Phys. Sci.
K.S. Milliken	B.Sc. (Queen's)	Res. Sci.
C.M. Mitchell	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
J. Ng-Yellin	B.A. (Carleton), B.Sc. (Ottawa U.)	Phys. Sci.
R.H. Packwood	B.Sc., Ph.D. (Birmingham)	Res. Sci.
G. Roy	M.Sc. (Silesian U.), Ph.D. (P.A.S.)	Res. Sci.
O. Vosikovsky	B.A.Sc., Ph.D. (Prague)	Res. Sci.
K.C. Wang	B.A.Sc., Ph.D. (Rensselaer)	Res. Sci.

Metallurgy Section

J.D. Boyd	**B.A.Sc. (Toronto), Ph.D. (Cambridge)**	**Section Head**
L.E. Collins	B.Sc., M.Sc. (Queen's), Ph.D. (M.I.T.)	Res. Sci.
A. Couture	B.A., B.A.Sc. (Laval), P.Eng.	Res. Sci.
D.M. Fegredo	B.Sc., M.Sc., Dipl. I.I.Sc. Ph.D. (Sheffield), M.I.M.	Res. Sci.
M.J. Godden	B.Met., Ph.D. (Sheffield)	Res. Sci.
R.F. Knight	B.Sc., M.Sc. (Queen's)	Res. Sci.
M.J.A. Lavigne	B.A., B.A.Sc., Ph.D. (Laval)	Res. Sci.
T.F. Malis	B.Sc., M.Sc., Ph.D. (Manitoba)	Res. Sci.
D.E. Parsons	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
M. Sahoo	B.Sc., B.E. (I.I.Sc., Bangalore) Ph.D. (U.B.C.), P.Eng.	Res. Sci.
M.T. Shehata	B.Eng. (Cairo), Ph.D. (McMaster)	Res. Sci.
C.S. Champion	**B.Sc (St. And), PGCE (Cambridge)**	**Tech. Editor**

STAFF CHANGES

The following persons were appointed to PMRL during this period:

M.J. Appleby	CR
Dr. D.L. Baragar	SE RES

S.A. Belcher	ST OCE
Dr. J.T. Bowker	SE RES
Dr. J.E.M. Braid	SE RES
Dr. G.J.C. Carpenter	SE RES
D. Carrigan	CR
C.S. Champion	PC
Dr. R.S. Chandel	SE RES
Dr. L.E. Collins	SE RES
J. Cooke	ST SCY
B.A. Euser	EG ESS
Dr. B. Faucher	SE RES
J.A. Gianetto	EG ES
J. Glasner	CR
S. Harris	ST TYP
Dr. H.M. Hindam	SE RES
R.J. Joseph	FDY
Y.A. Lafrenière	EG ESS
G. Landry	PC
J.A. Mainville	PC
Dr. D.K. Mak	SE RES
Dr. T.F. Malis	SE RES
R.A. Matte	ENG
G. Morin	ENG
S.L. Murray	EG ESS
Dr. A. Palmer	SE RES
B. Perry	ST OCE
R.R. Poirier	EG ESS
Dr. G. Roy	SE RES
L. Seto	EG ESS
Dr. J.J.M. Too	SE RES
C.R. Trinque	EG ESS

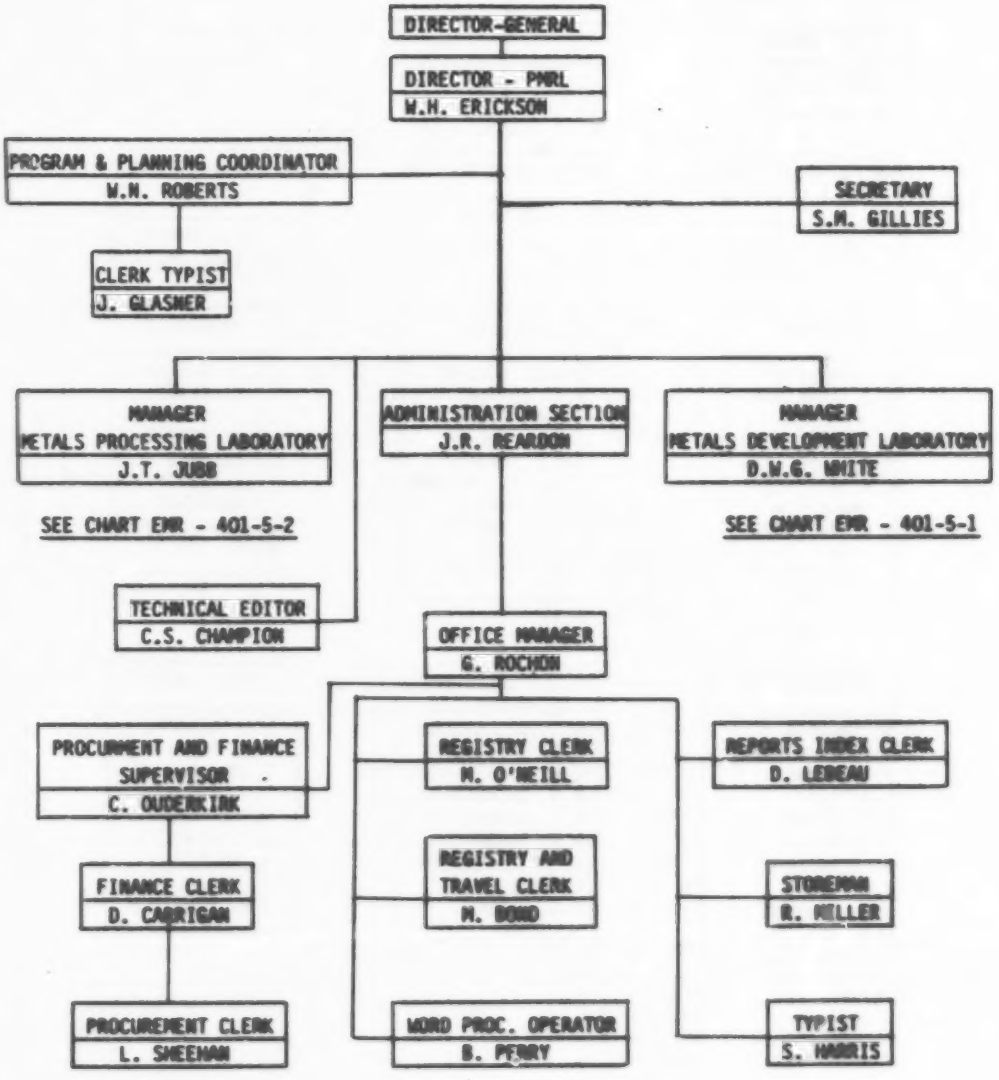
The following persons separated from PNRL during this period:

S.A. Belcher	Transferred
Dr. R. Bell	Resigned
J.G. Caron	Retired
F. Champagne	Resigned
D. Lavigne	Transferred
Dr. W.J.A. Lavigne	Retired
A. Levesque	Retired
F. Marleau	Resigned
Dr. Z. Paley	Deceased
Dr. W.A. Pollard	Retired
I. Santowski	Transferred
E.B. Williams	Transferred

CURRENT STATUS

Professionals	Non-professionals	Total
63	80	143

PMRL ORGANIZATIONAL CHARTS



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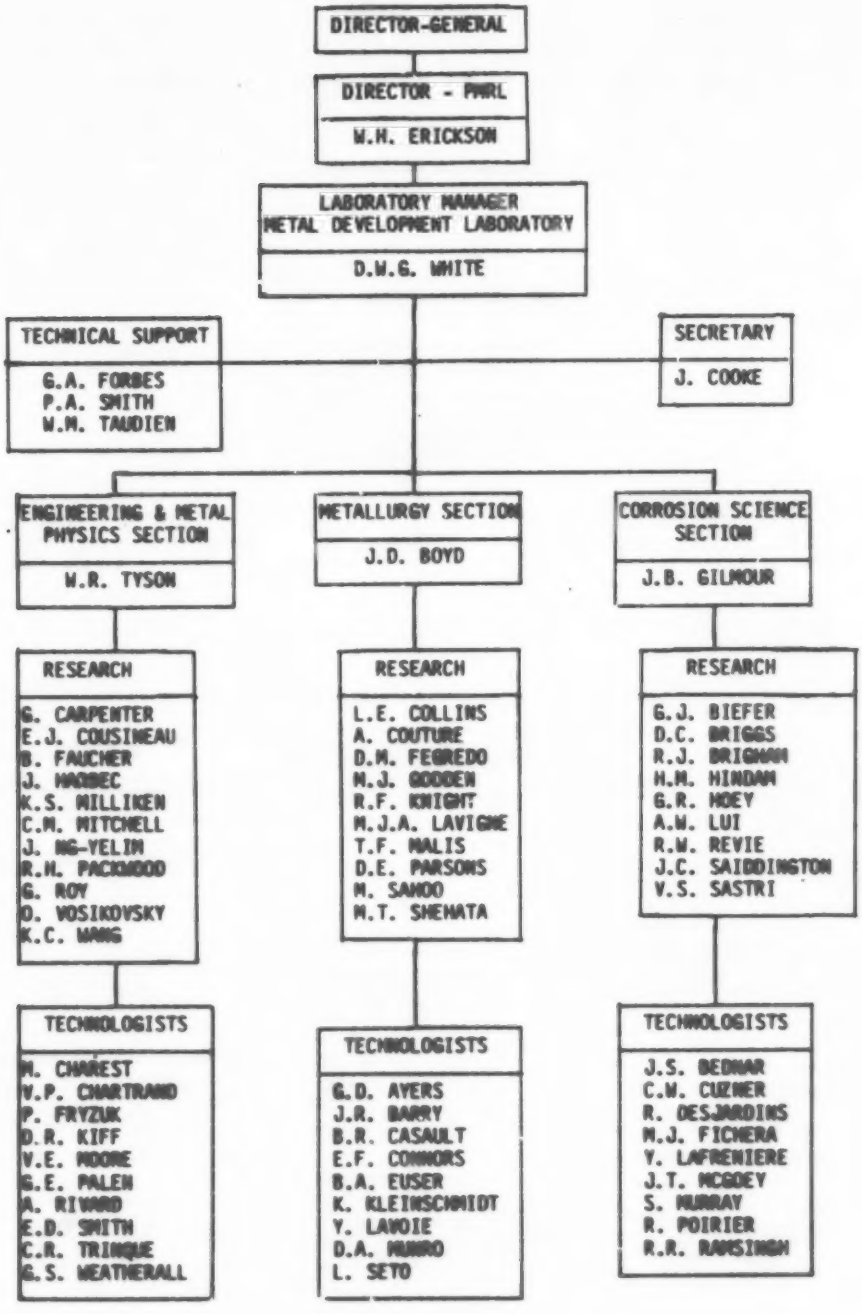

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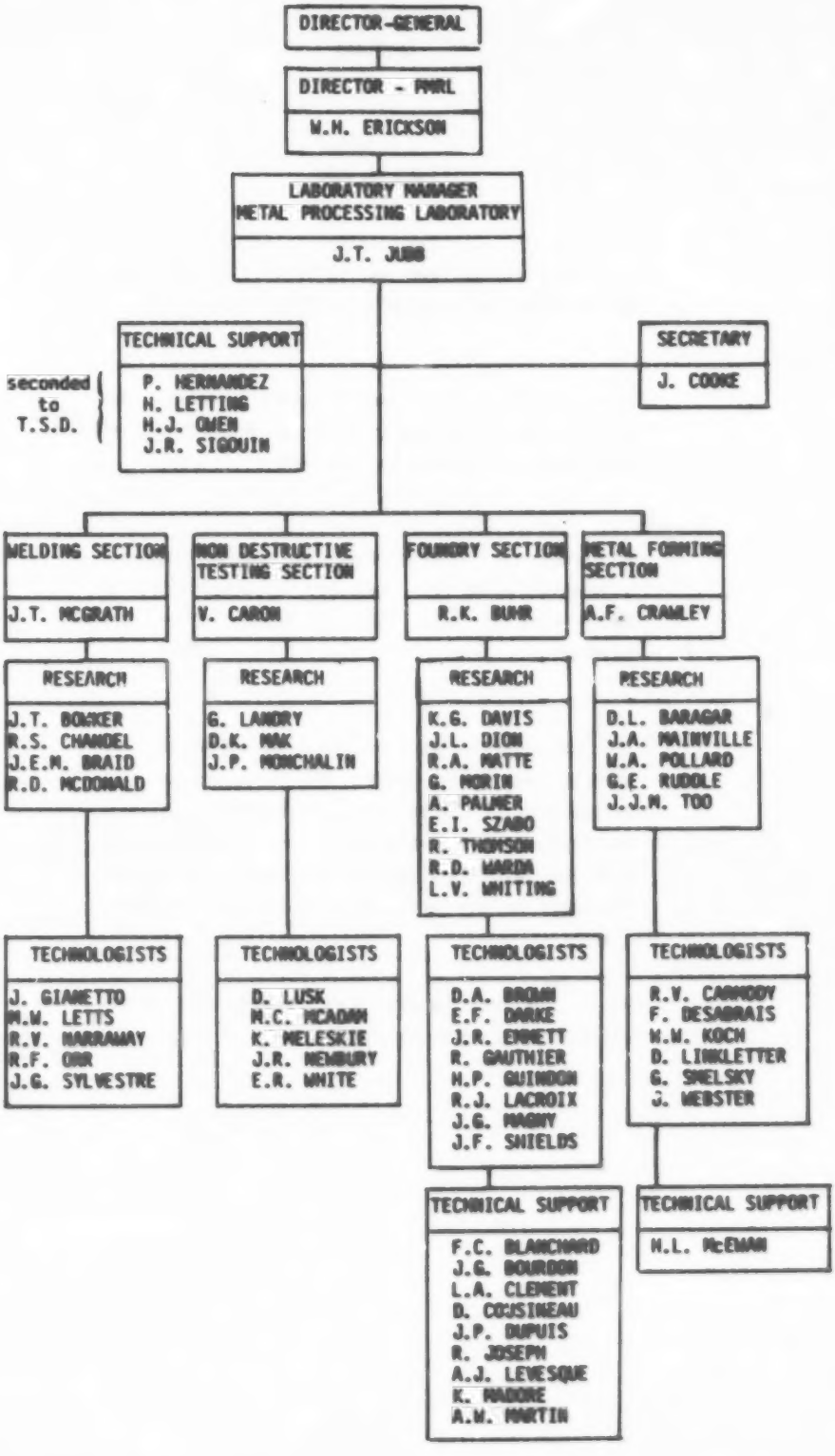

OBITUARY

Zvi Paley
1929 to 1983

Zvi Paley passed away on March 24, 1983 at the Ottawa Civic Hospital after a long illness.

Born in Poland, Zvi came to Canada in 1959. He obtained his first degree in Israel and a Ph.D. in Metallurgical Engineering from McGill in 1966.

As a research fellow at M.I.T. he applied his considerable talent for language in translating a major work on heat flow in welding from the Russian.

Zvi jointed PMRL as a research scientist in the welding section in 1966. His research on the weldability of a wide range of engineering alloys was featured by the development of a computer program for describing the thermal history of welds, for which he has achieved internationall recognition.

He is survived by his wife Rachel, and three children, Dror, Ron and Tal.